



**US Army Corps  
of Engineers**



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# **IMPULSIVE WAVES GENERATED BY FALLING WEIGHTS IN SHALLOW WATER**

## **Laboratory Investigation**

by

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<p>Laboratory tests were conducted to determine transient wave train characteristics (wave height and time series) generated as a result of steel discs falling into shallow water. Steel plates ranging from 2.8 to 6.0 feet in diameter were dropped from various heights into test basins with water depths ranging from 0.2 to 1.2 feet. Capacitance-type wave gages were used to obtain wave height data at various distances from the edge of the steel discs. Water current magnitudes also were obtained at selected locations, and photographic coverage was used to document vessel movements of small-scaled submarines. Instrumentation was installed on the steel discs to measure acceleration, and an automated data acquisition and control system was used to obtain and analyze wave data. Plots are included that present results of these tests.</p>					
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## SUMMARY

Military coastal facilities and vessels are vulnerable to damage from explosion-generated water waves. The explosion source may be located either in deep water off the continental shelf or in shallow water near the harbor facility. The deepwater location is most efficient for wave generation, but significant wave energy can be lost during wave propagation over the continental shelf. Presently, a lack of adequate wave data exists for explosions detonated in shallow water.

The tests described herein used falling weights to simulate explosion sources. They were conducted to study wave generation and propagation in shallow water near the explosion source and to refine existing scaling relationships because there is presently a lack of adequate data for explosion-generated waves in shallow water.

The experimental data obtained provided an excellent data set for the calibration and verification of a theoretical shallow-water wave generation and propagation model. Test results were documented with plots of wave train time-histories as waves propagated from the source. Acceleration data and current magnitudes also were plotted. High quality movie footage and videotape were obtained depicting vessel motions at the edge of the wave plume near the source.

## PREFACE

This report presents the results of a study involving impulsive waves generated by falling weights in shallow water. The investigation evolved from Work Unit 00047, "Explosion-Generated Water Waves," to assess the vulnerability of coastal military facilities and vessels to explosion-generated water waves. The work was sponsored by the Defense Nuclear Agency (DNA), Washington, DC, and funds were authorized on 18 December 1987 and 8 February 1989.

The investigation was conducted at the US Army Engineer Waterways Experiment Station (WES) during the period of February 1988 to July 1989 by personnel of the Wave Processes Branch (WPB), Wave Dynamics Division (WDD), Coastal Engineering Research Center (CERC), under the direction of Dr. James R. Houston, Chief of CERC; Mr. Charles C. Calhoun, Jr., Assistant Chief of CERC; Mr. C. Eugene Chatham, Jr., Chief of WPB; and Mr. Douglas G. Outlaw, former Chief of WDD. Laboratory tests were conducted by Messrs. Hugh F. Acuff, Civil Engineering Technician; David Daily, Electronics Technician; and William G. Henderson, Computer Clerk, under the supervision of Mr. Robert R. Bottin, Jr., Physical Scientist, WDD. This report was prepared by Mr. Bottin. Tests were conducted in consultation with Dr. Bernard J. Le Méhauté, Dr. Shen Wang, and Mr. Tarang Khangaonkar of the University of Miami. This report was typed by Ms. Lee Ann Germany, WPB, and edited by Ms. Lee T. Byrne, Information Technology Laboratory, WES.

During the course of the investigation, liaison was maintained between WES and DNA by telephone communications, conferences, and progress reports.

The following personnel visited WES to observe laboratory experiments and/or participate in conferences during the course of the study:

LCDR Paul H. Stoebert	Defense Nuclear Agency
Lt Camy Carlin	Defense Nuclear Agency
Mr. Stan Halperson	Defense Intelligence Agency
LCDR George Ziska	Joint Strategic Tactical
Planning Staff (JSTPS)	
Dr. Bernard Le Méhauté	University of Miami

COL Larry B. Fulton, EN, was Commander and Director of WES during publication of this report. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)  
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to  
SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
feet	0.3048	metres
inches	25.4	millimetres
kilotons (nuclear equivalent of TNT)	4.184	terajoules
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square metres

IMPULSIVE WAVES GENERATED BY FALLING WEIGHTS IN SHALLOW WATER  
Laboratory Investigation

SECTION 1  
INTRODUCTION

1.1 BACKGROUND

As part of an investigation entitled "Explosion-Generated Water Waves" sponsored by the Defense Nuclear Agency, the US Army Engineer Waterways Experiment Station (WES) conducted explosion wave field tests in a shallow-water basin, model tests of predicted explosion wave train characteristics in a generalized harbor inlet model, and model tests of vessel response in a generalized model for a typical mooring system.

The field tests were conducted to determine the wave generation and propagation characteristics resulting from a range of charge sizes and water depths at various distances from the point of detonation. The test results were published (Reference 1) and used for calibration and verification of a numerical shallow-water explosion wave generation model (Reference 2).

Calculated wave train results from the wave generation model were used to develop control signals for a directional spectral wave generator that was used to generate predicted explosion wave train characteristics during tests of wave generation and propagation in a 1:250-scale generalized harbor inlet model. Wave train characteristics simulating low-yield nuclear explosions ranging from 100 to 500 kilotons\* were generated by the directional spectral wave generator. Results of these tests were published (Reference 3) and used to calibrate and verify a theoretical model of wave propagation/harbor interaction that can be applied to other sites of interest (Reference 2).

Predicted explosion wave train characteristics (wave form and angle of approach) obtained from the harbor inlet model were used as input conditions for a 1:50-scale generalized model used to determine vessel response for a typical mooring system. Accelerometers were installed in a 460-foot-long (scaled) submarine to measure vessel motions, due to the acceleration of gravity, for wave trains reproduced by an electrohydraulic wave generator representing yields ranging from 100 to 500 kilotons. These model tests were

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\* A table of factors for converting non-SI units of measurements to SI (metric) units is presented on page vii.

published (Reference 4) and used for calibration and verification of a theoretical model of vessel response that can be applied to other sites of interest (Reference 5).

During this portion of the study, the characteristics of impulsive waves resulting from dropping steel discs into relatively shallow water were investigated. Wave measurements, wave train time-histories, velocity data, and photographic coverage of vessel motions of small-scaled submarines were obtained for waves generated by steel discs dropped from varying heights into a test basin with varying water depths. Limited data are currently available involving shallow-water waves generated by falling weights. Tests were conducted in the late 1940's (Reference 6); however, results were limited to only crest-to-trough wave heights.

## 1.2 OBJECTIVES

The overall objective of the work unit was to develop theoretical models to assess the vulnerability of coastal military facilities and vessels to explosion-generated water waves produced by nuclear weapons in shallow water. Characteristics of waves generated in shallow water are different from deepwater wave characteristics. Prior studies have shown that waves are most efficiently generated in relatively deep water. Deepwater explosions near the continental shelf will generate waves that will travel over the shelf and produce a devastating region of wave breaking. This effect may cause capsizing of naval vessels or violent movement and forces loading on submerged submarines. Wave breaking on the continental shelf, however, reduces wave energy striking a harbor, and an explosion with a much lower yield near or within a harbor may produce much larger waves. Due to a lack of adequate data for explosion waves detonated in shallow water (particularly in the near region), the tests reported herein were conducted to:

- a. Develop an experimental technique for simulating explosion-generated waves at small scales in physical models where a range of test conditions can be simulated without damage to models or facilities.
- b. Obtain data to indicate the magnitude of explosion wave effects in the near field.

In addition, tests results were used for calibration and verification of a theoretical model of wave generation and propagation in shallow water using the flat plate technique that can be applied to other test conditions and charge yields.

SECTION 2  
LABORATORY, EQUIPMENT, AND TEST PROCEDURES

2.1 BASIN DESCRIPTIONS

The initial laboratory tests were conducted in one of the flat hydraulic model basins at WES. This basin was approximately 140 by 140 feet and was 1.5 feet deep. A fiber wave absorber was placed around the inside perimeter of the basin walls to minimize wave reflections; however, test results from dropping the steel plates were obtained prior to the influence of any reflected wave energy. The main function of the wave absorber was to hasten the stilling of the basin. The second test series was conducted in a 1:250-scale generalized harbor inlet physical model (Figure 1). More information on the physical model may be obtained from Reference 3.

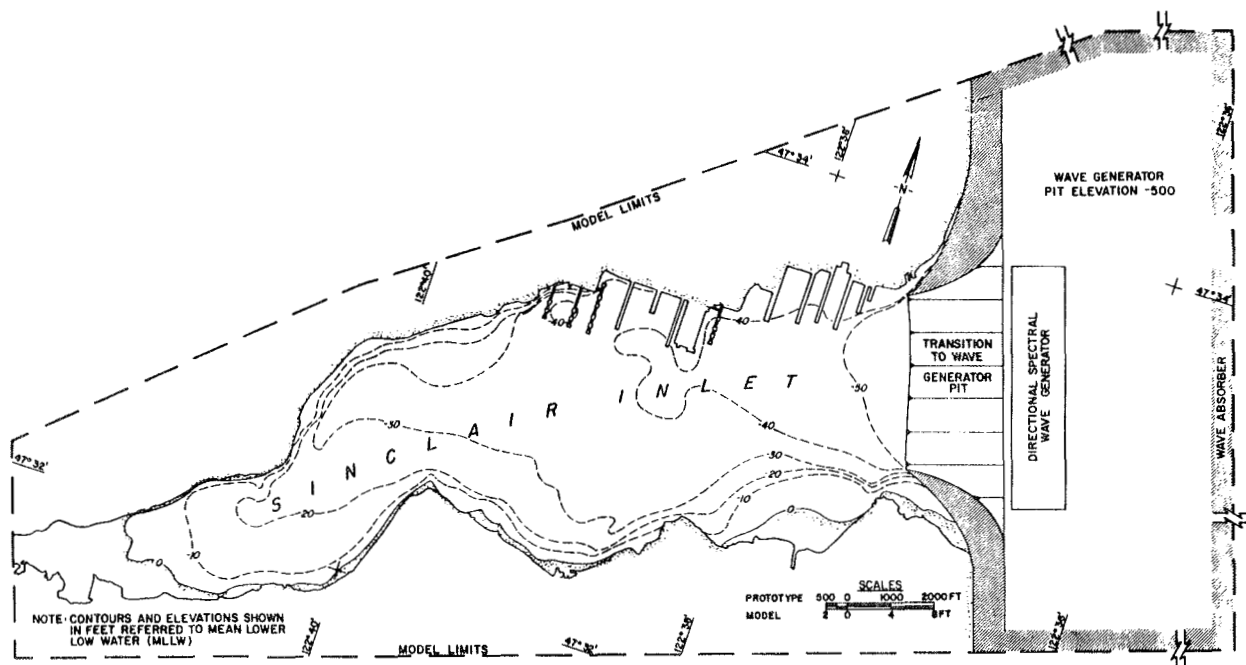


Figure 1. Generalized harbor inlet physical model layout.

The steel discs were dropped in the physical model in areas where depths were about 0.24 feet deep, equivalent to 60 feet in the prototype (including tides). Results presented in this report are shown in model or actual units of measurement obtained. Froude's model law (Reference 7) and a specific weight scale ( $\gamma_r$ ) of 1:1 may be used to convert model units to prototype values (i.e. 1:250-scale). Scale relations are as follows for a 1:250-scale model:

<u>Characteristic</u>	<u>Dimension*</u>	<u>Model:Prototype Scale Relation</u>
Length	L	$L_r = 1:250$
Area	$L^2$	$A_r = L_r^2 = 1:62,500$
Volume	$L^3$	$V_r = L_r^3 = 1:15,625,000$
Time	T	$T_r = L_r^{1/2} = 1:15.81$
Velocity	L/T	$V_r = L_r^{1/2} = 1:15.81$
Force	F	$F_r = L_r^3 \gamma_r = 1:15,625,000$

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\* Dimensions are in terms of length and time.

## 2.2 EQUIPMENT AND TEST PROCEDURES

In the initial test series, impulsive waves were generated in the laboratory by dropping steel discs into the water. The discs were 1-inch thick; were 2.8, 4.8, and 6.0 feet in diameter; and weighed 145, 865, and 1,154 pounds, respectively. They were suspended from a fabricated frame by 3/16-inch cable at heights of 0.75, 3, and 6 feet above the water surface. The steel plates were leveled while in suspension prior to release. To ensure instant release of the discs, explosive cable cutters (guillotines) were detonated to drop the plates. Tests were conducted with water depths of 0.2, 0.6, 0.9, and 1.2 feet in the flat basin, and a depth of about 0.24 feet was used in the generalized inlet model.

An automated data acquisition system was used to secure, analyze, and store wave data at selected locations that were various distances from the steel discs. Basically, through the use of a Microvax computer, the acquisition system recorded the voltage variation of capacitance-type wave sensors. These sensors measured the changes in water surface elevation with respect to time. The data were then analyzed to obtain wave train characteristics. Wave gage locations for tests in the flat model basin are shown in Figure 2. Gages were placed distances ranging 0.5 to 12 feet from the edge of the discs; therefore, they were moved to adjust for the different diameters of the disc being used in the tests. Wave gage locations for the second test series conducted in the generalized harbor model are shown in Figure 3. The gages were placed along the sides of one of the pontoon piers, and the disc used for these tests was positioned where the distances between its edge and the end of

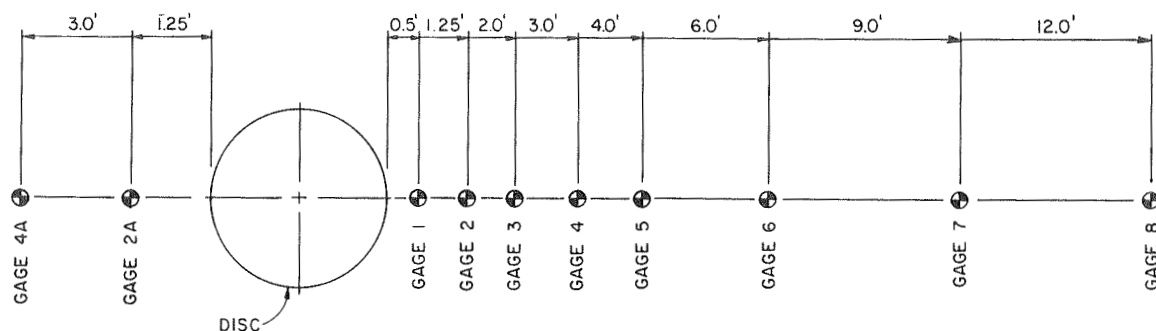


Figure 2. Wave gage locations in flat model basin.

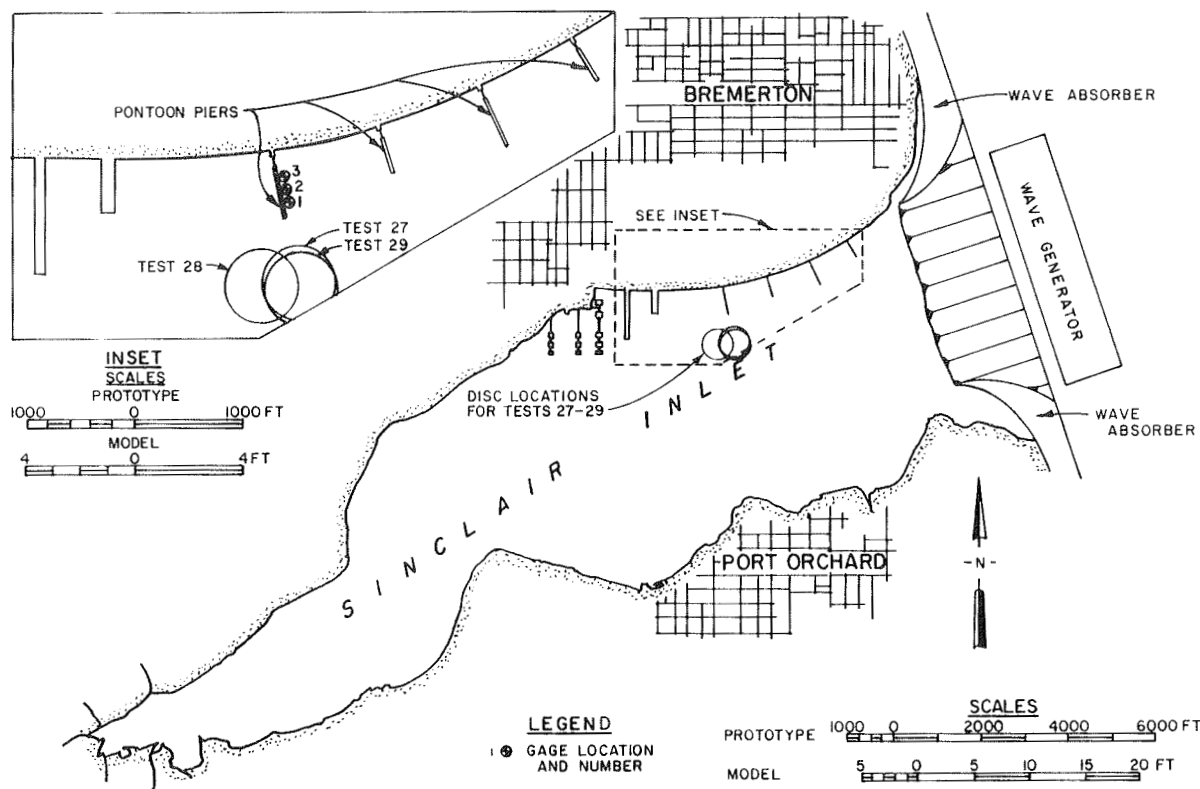


Figure 3. Wave gage locations in generalized harbor model.

the pontoon pier were 1.0 and 1.24 feet. The locations, where the disc was dropped in the model, also are shown in Figure 3.

Current magnitudes resulting from the impulsive generated waves in the initial test series were obtained with a highly sensitive miniature current meter system. The measuring head consisted of a five-blade rotor mounted on a stainless steel spindle which terminated in fine conical pivots that ran in jewel bearings. The flowmeter was located a distance of 1.25 feet (wave Gage 2 location) from the edge of the steel discs. Current magnitudes were plotted on an oscillograph recorder as the waves passed the probe.

Three small-scale submarines were fabricated in the laboratory (Figure 4). They were 1.92 feet long and 0.142 feet in diameter and were moored at a draft of 0.134 feet during testing in the flat model basin. The vessels

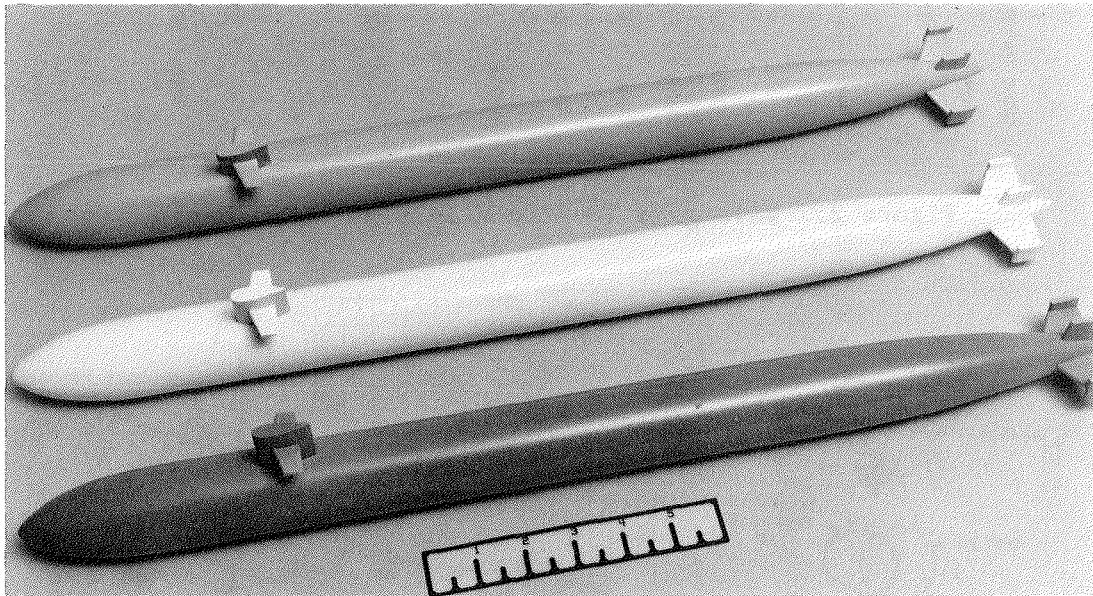


Figure 4. View of small-scale submarines used during testing.

were placed 0.5, 3.0, and 6.0 feet from the edge of the steel discs with their bows facing the discs. Extensive photographic coverage, including high-speed motion picture footage and videotape footage, was secured to analyze vessel motions close to the source of the impulsive waves. Photographic coverage of water columns resulting from dropping the various plates also was obtained for some tests in the flat model basin.

One of the small-scale submarines was used during the second test series in the generalized harbor model. It was moored adjacent to one of the floating pontoon piers with its bow facing the shore from 0.5 to 1.0 foot from the bank. A steel disc was dropped with its edge 1.0 and 1.24 feet seaward of the outer end of the pier, and vessel motions were analyzed through videotape footage. A small protractor and pendulum were mounted to the front side of the vessel to obtain measurements of its roll motions.

Accelerometers were installed on the steel plates for some of the tests in the flat model basin to measure acceleration of the discs as they were dropped. Acceleration, in the vertical direction, was obtained during free flight, as the disc impacted the water surface, and as it settled to the basin floor.

## SECTION 3

### TESTS AND RESULTS

#### 3.1 TESTS

Wave heights were secured for 26 test conditions in the flat model basin and 3 conditions in the generalized inlet model. Wave train time-history plots were plotted graphically for all test conditions for the selected gage locations, and the height of the first (leading) wave was recorded and shown in tables for the various wave gage locations. Vessel motions were documented via photography, and current magnitudes were plotted with maximum velocities recorded in tabular form for test conditions in the flat basin. Acceleration data plots and photographs of various water columns also were secured for selected test conditions. Descriptions of the various test conditions are shown in Table 1.

#### 3.2 TEST RESULTS

Wave train time-history plots obtained in the flat model basin (Tests 1-26) are shown in Appendix A for the test conditions shown in Table 1. Heights of the waves obtained are shown in Table 2 for the various test conditions. The wave height is the distance between the crest and the trough of the wave.

Plots of current magnitude versus time are shown in Appendix B for test conditions conducted in the flat model basin (Tests 1-26). Maximum magnitudes secured for the various test conditions are shown in Table 3.

Displacement of the small-scale submarines in the flat model basin was obtained with high-speed motion picture photography and videotape footage. Selected photographs showing the movement of the submarines as the impulsive waves passed the vessels are shown in Appendix C for representative test conditions. Plots depicting the pitch of the small-scale submarines (measured from the motion picture and videotape footage) are shown in Figure 5 for Tests 1-24.

Acceleration data obtained for the steel discs in the flat model basin are presented in Appendix D for typical test conditions. Acceleration data were filtered in some instances with 25, 50, and/or 100 Hz low pass filters.

Wave train time-histories obtained in the generalized inlet model (Tests 27-29) are presented in Appendix E for the test conditions shown in Table 1. Heights of the waves are shown in Table 4 for the conditions tested.



Table 1. Description of test conditions.

<u>Test number</u>	<u>Disc diameter, ft</u>	<u>Height of fall, ft</u>	<u>Depth of water, ft</u>
<u>Flat model basin</u>			
1	2.8	3	0.2
2	2.8	6	0.2
3	2.8	3	0.6
4	2.8	6	0.6
5	2.8	3	0.9
6	2.8	6	0.9
7	2.8	3	1.2
8	2.8	6	1.2
9	4.8	3	0.2
10	4.8	6	0.2
11	4.8	3	0.6
12	4.8	6	0.6
13	4.8	3	0.9
14	4.8	6	0.9
15	4.8	3	1.2
16	4.8	6	1.2
17	6.0	3	0.2
18	6.0	6	0.2
19	6.0	3	0.6
20	6.0	6	0.6
21	6.0	3	0.9
22	6.0	6	0.9
23	6.0	3	1.2
24	6.0	6	1.2
25	6.0	0.75	0.6
26	6.0	0.75	0.2
<u>Generalized inlet model</u>			
27-29*	2.8	6	0.24

\* Edge of steel disc 1.0 foot from outer end of floating pontoon pier along its centerline axis for Test 27; 1.24 feet and 30 degrees to pier axis for Test 28; and 1.24 feet along centerline axis for Test 29.

Table 2. Maximum wave heights (crest to trough) obtained in the flat model basin.

Test number	Maximum wave heights (ft) at indicated gage location for various tests							
	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
1	0.6	0.74	0.37	0.36	0.14	0.17	0.19	0.11
2	0.45	0.8	0.49	0.43	0.11	0.19	0.21	0.15
3	1.11	0.94	0.5	0.46	0.41	0.27	0.22	0.18
4	0.97	1.06	0.68	0.55	0.52	0.36	0.29	0.22
5	1.03	0.89	0.52	0.44	0.37	0.28	0.23	0.19
6	1.04	0.95	0.65	0.55	0.46	0.34	0.24	0.20
7	0.79	0.73	0.49	0.47	0.39	0.34	0.26	0.20
8	1.21	0.80	0.69	0.54	0.51	0.42	0.33	0.26
9	0.58	0.70	0.37	0.36	0.57	0.19	0.28	0.15
10	0.57	0.88	0.59	0.45	0.60	0.17	0.27	0.16
11	0.95	0.86	0.61	0.60	0.56	0.39	0.37	0.27
12	0.96	1.06	0.76	0.65	0.66	0.45	0.39	0.35
13	0.94	0.89	0.62	0.58	0.47	0.34	0.37	0.23
14	1.16	0.87	0.81	0.70	0.62	0.41	0.47	0.29
15	0.77	0.61	0.59	0.55	0.46	0.41	0.29	0.25
16	1.24	0.78	0.78	0.69	0.58	0.46	0.37	0.30
17	0.61	0.70	0.45	0.37	0.65	0.20	0.27	0.17
18	0.53	0.82	0.56	0.35	0.34	0.21	0.29	0.19
19	0.94	0.90	0.64	0.65	0.60	0.41	0.42	0.33
20	0.87	1.03	0.78	0.70	0.72	0.46	0.46	0.39
21	0.94	0.85	0.66	0.65	0.63	0.43	0.33	0.26
22	1.16	0.82	0.82	0.71	0.70	0.47	0.45	0.36
23	0.78	0.60	0.63	0.59	0.49	0.42	0.36	0.27
24	1.10	0.68	0.86	0.68	0.65	0.48	0.42	0.34
	Gage 1	Gage 2	Gage 2A*	Gage 3	Gage 4	Gage 4A	Gage 5	Gage 6
25	0.87	0.53	0.63	0.53	0.50	0.44	0.44	0.35
26	0.54	0.35	0.44	0.33	0.27	0.29	0.23	0.16

\* Gages 2A and 4A for Tests 25 and 26 were the same distances from the edge of the disc as Gages 2 and 4, respectively, but on the opposite side of the disc.

Table 3. Maximum current magnitudes obtained in the flat model basin.

<u>Test number</u>	<u>Maximum current magnitude, fps</u>	<u>Test number</u>	<u>Maximum current magnitude, fps</u>
1	1.49	14	2.05
2	1.07	15	1.53
3	1.56	16	1.97
4	2.26	17	2.89
5	1.34	18	1.69
6	1.75	19	2.10
7	1.25	20	2.48
8	1.66	21	1.75
9	2.92	22	2.16
10	1.44	23	1.59
11	2.36	24	1.94
12	1.94	25	1.54
13	1.75	26	1.90

Measurements of the small-scale submarine roll characteristics were obtained for Tests 27 and 28 via videotape footage, with the vessel 0.5 and 1.0 feet from the bank, adjacent to the floating pontoon pier. For Test 27, with the vessel 0.5 foot from the bank, the vessel rolled in the starboard and port directions several times with maximum roll angles of 28 and 29 degrees for the starboard and port directions, respectively. With the submarine 1.0 foot from the bank, maximum starboard and port angles were 28 and 20 degrees, respectively. For Test 28, the vessel rolled 55 and 26 degrees in the starboard and port directions, respectively, when positioned 1.0 foot from the bank, and 38 degrees in each direction when it was 0.5 foot from the bank. An additional test, similar to Test 27 with the vessel 0.5 foot from the bank, was conducted, but the disc was dropped at a location 0.5 foot shoreward and 0.5 foot from the edge of the floating pier. For this test, the submarine rolled with maximum roll angles of about 80 to 90 degrees in both the starboard and port directions.

### 3.3 DISCUSSION OF TEST RESULTS

Examination of the wave train time-history plots obtained in the flat model basin (Appendix A) reveals very sharp-peaked nonlinear waves

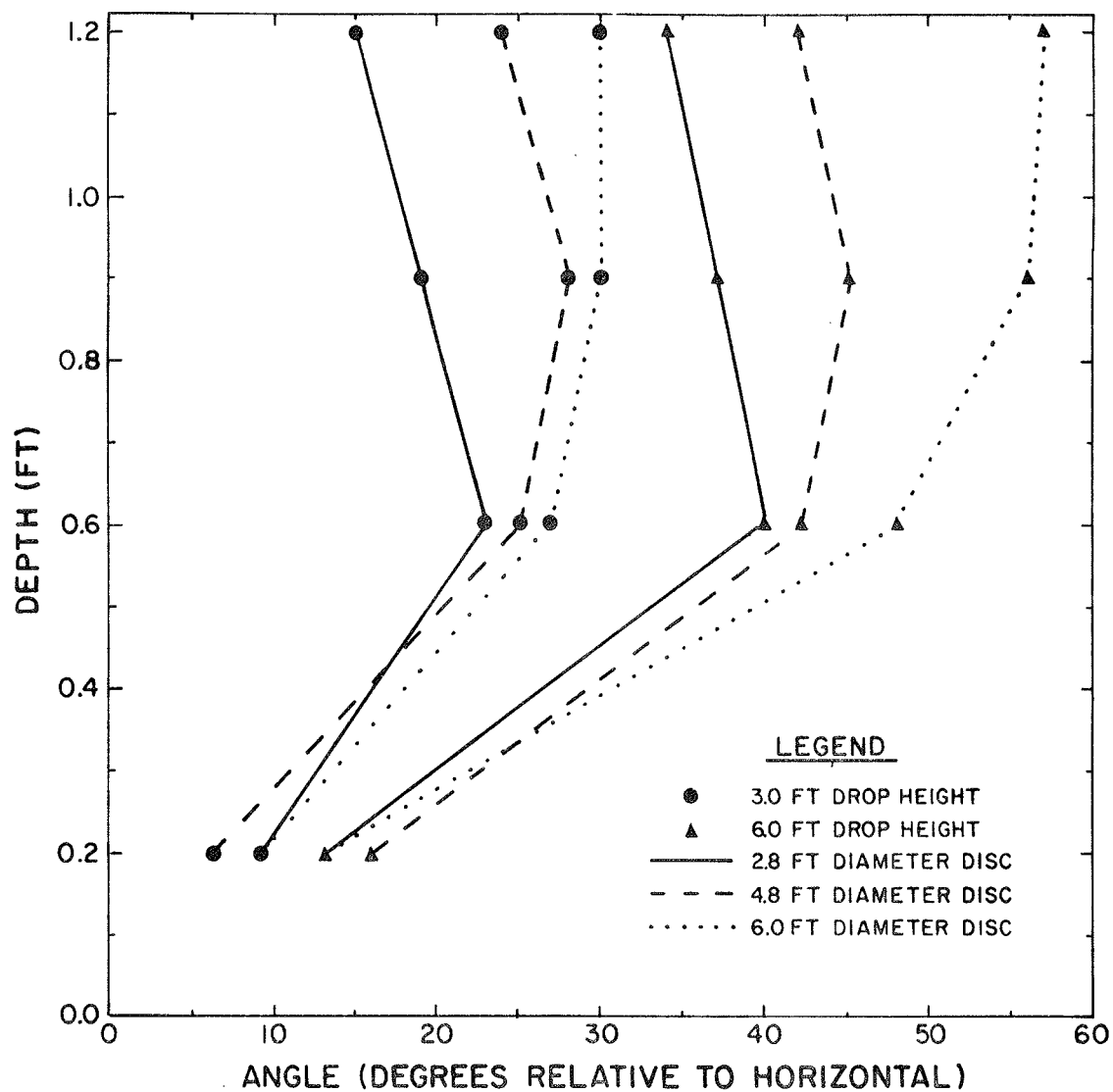


Figure 5. Submarine pitch measured in flat model basin.

Table 4. Maximum wave heights (crest to trough) obtained in the generalized inlet model.

Test number	Gage 1	Gage 2	Gage 3
27	1.00	0.55	0.35
28	0.97	0.73	0.49
29	1.07	0.46	0.43

particularly in the near region (region closest to edge of plate and subsequent plume). In general, test results indicated that the depth of water in the basin was the most critical factor with regard to the maximum wave heights that can be generated by the falling weights. The size of the dropped plate and the height of fall were less critical than the water depth in generating maximum wave heights.

Maximum current magnitudes for the various test conditions in the flat model basin ranged from 1.07 to 2.92 feet per second (fps). The 2.8-foot-diameter plate resulted in maximum velocities with the 0.6-foot water depth; however, the 4.8- and 6-foot plates resulted in maximum velocities with the 0.2-foot depth. In general, maximum velocities occurred in less than 1 second for plates with the 0.2- and 0.6-foot depths and between 1 and 2 seconds for plates with the 0.9- and 1.2 foot depths.

Displacement of the model submarines (pitch) in the flat model basin as a result of the falling weights indicated that the pitch of the vessels followed various trends. Discs dropped from the higher heights of fall resulted in greater pitch angles for the vessels, as compared with the lower heights of fall. In addition, the larger the diameter of the disc, in general, the greater the pitch of the vessel.

Wave train time-history plots obtained in the generalized inlet model indicated very sharp-peaked nonlinear waves. Maximum wave heights varied only slightly by changing the location of the drop. The disc dropped at an angle to the floating pontoon pier, however, resulted in larger wave heights at the center of the pier (Gage 2) than the drops along the axis of the pier.

Measurements of the small-scale submarine roll characteristics in the generalized inlet model indicated variable roll angles. Slight moves in the plate drop location resulted in relatively greater differences in roll angles. These roll tests were of a preliminary nature, and more extensive tests should be conducted using a wider range of conditions to accurately establish trends.

## SECTION 4

### CONCLUSIONS

The experimental technique employed during these tests allowed for the simulation of explosion-generated waves at small scales in physical models where a range of conditions were simulated without damage to model facilities.

The experimental data obtained (wave train time-histories), using falling weights to simulate explosion sources, provide an excellent data set for calibration and verification of a shallow-water explosion wave generation model, particularly in the near field. Combined with limited shallow-water data from other sources and larger charge yields, the test series provides data for the time-dependent wave train analysis. Wave train transformation as waves propagate radially from the source can readily be verified.

The experiments incorporating vessel motion observations (pitch and roll) provided a better understanding of vessel movements in the near field of an explosion source; however, they are considered of a preliminary nature. They may be thought of as pilot studies for more extensive experiments that should be made at a later date.

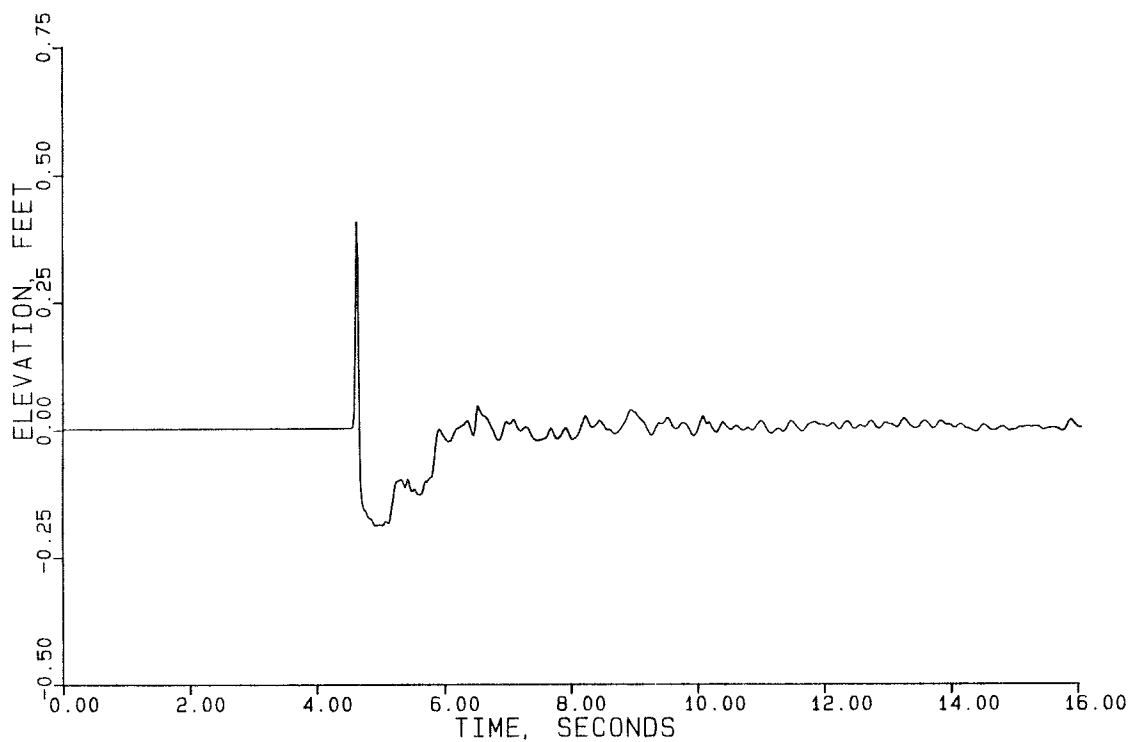
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2. B. J. Le Méhauté, S. Wang, and C. C. Lu. "Theories of Impulsion Generated Water Waves (U)," Technical Report in preparation (Secret), Defense Nuclear Agency, Washington, DC.
3. R. R. Bottin, Jr., and D. G. Outlaw. 1988 (Jun). "The Vulnerability of Coastal Military Facilities and Vessels to Explosion-Generated Water Waves; Report 1: Explosion Generated Wave Measurements, Experimental Model Investigation (U)," Technical Report CERC-88-2 (Confidential), US Army Engineer Waterways Experiment Station, Vicksburg, MS.
4. R. R. Bottin, Jr., and D. G. Outlaw. 1988 (Jun). "The Vulnerability of Coastal Military Facilities and Vessels to Explosion Generated Water Waves; Report 2: Measurements of Vessel Response, Experimental Model Investigation (U)," Technical Report CERC-88-2 (Confidential), US Army Engineer Waterways Experiment Station, Vicksburg, MS.
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6. J. W. Johnson and K. J. Bermel. 1949 (Apr). "Impulsive Waves in Shallow Water as Generated by Falling Weights," Transactions, American Geophysical Union, Vol 30, No. 2, pp 223-230, Washington, DC.
7. American Society of Civil Engineers. 1942. "Hydraulic Models," Manuals of Engineering Practice No. 25, Committee of the Hydraulic Division of Hydraulic Research, New York.

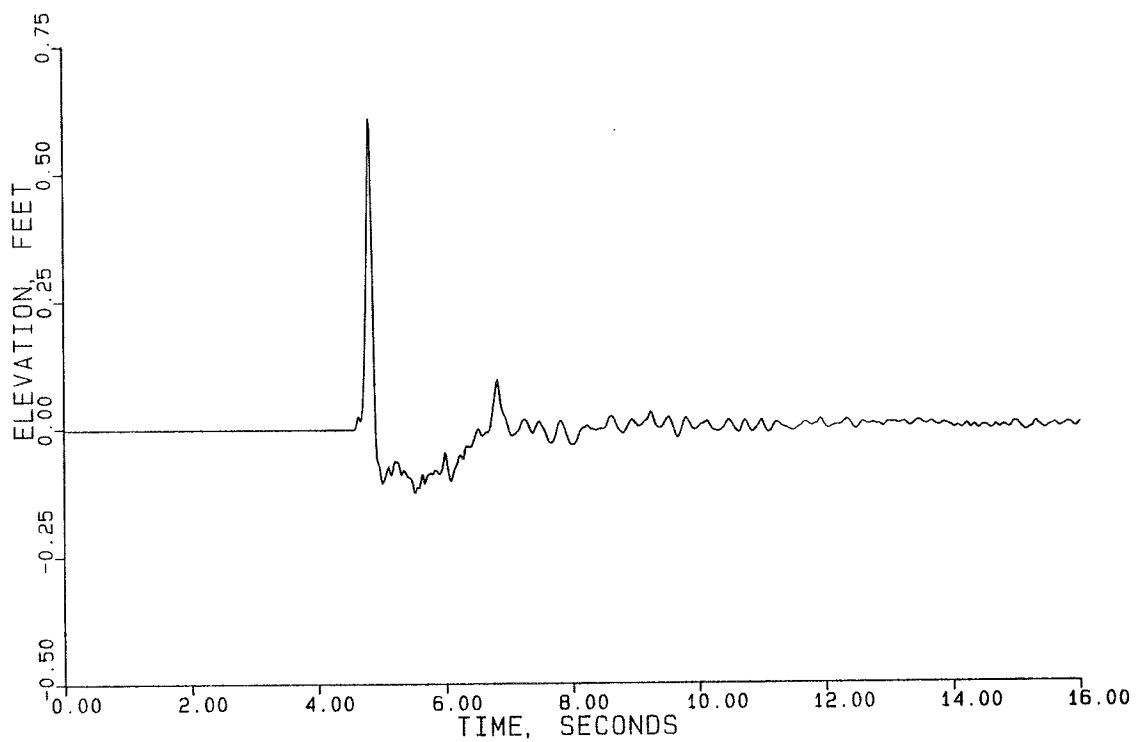
APPENDIX A  
WAVE TRAIN TIME-HISTORIES OBTAINED IN FLAT MODEL BASIN

Wave train time-histories obtained in the flat model basin are shown in this appendix. The test number shown on each plot corresponds to test conditions shown in Table 1 in the main body of the report. Gage numbers also are identified on each figure. In some instances, the trough of the first wave may have dipped below the bottom of the wave rod at the Gage 1 location only; however, data for the peak of the leading wave were obtained and are considered valid.

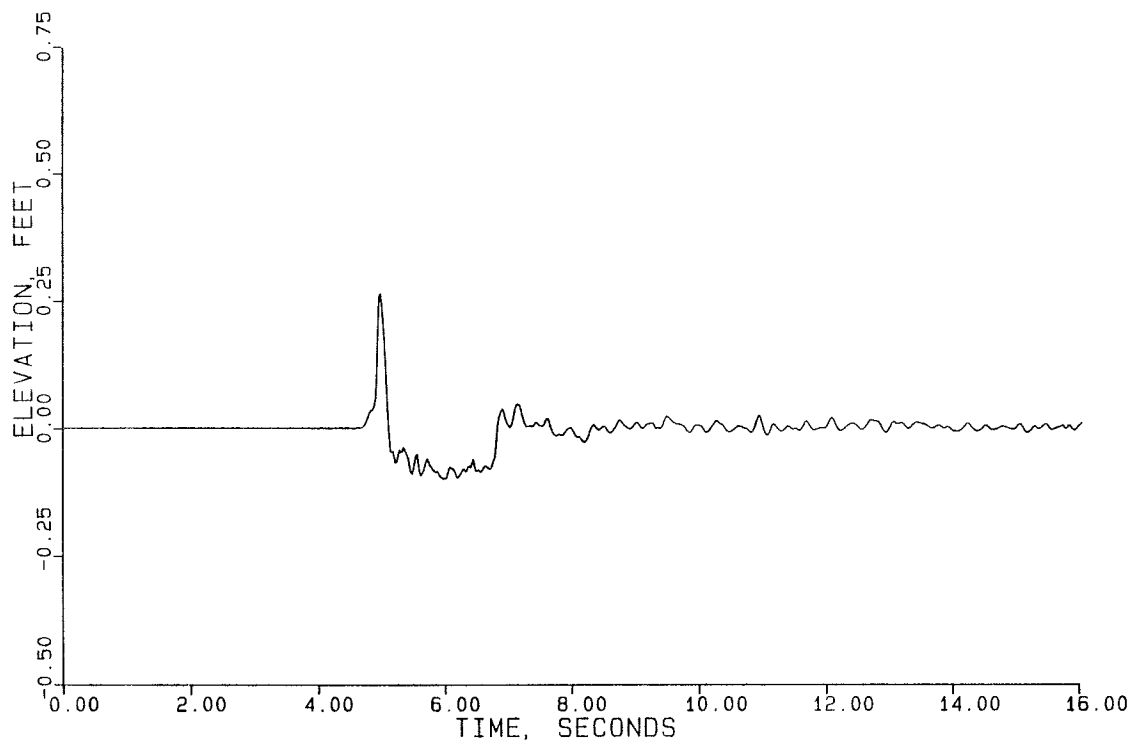




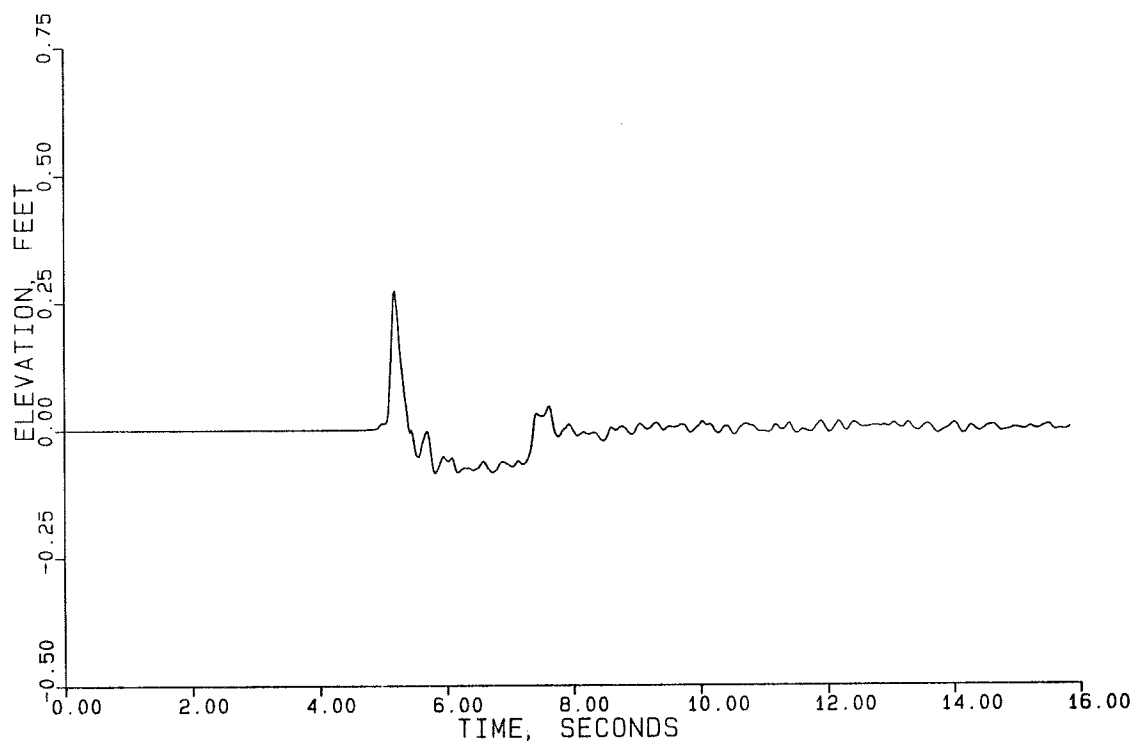
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TEST 1 , GAGE 1



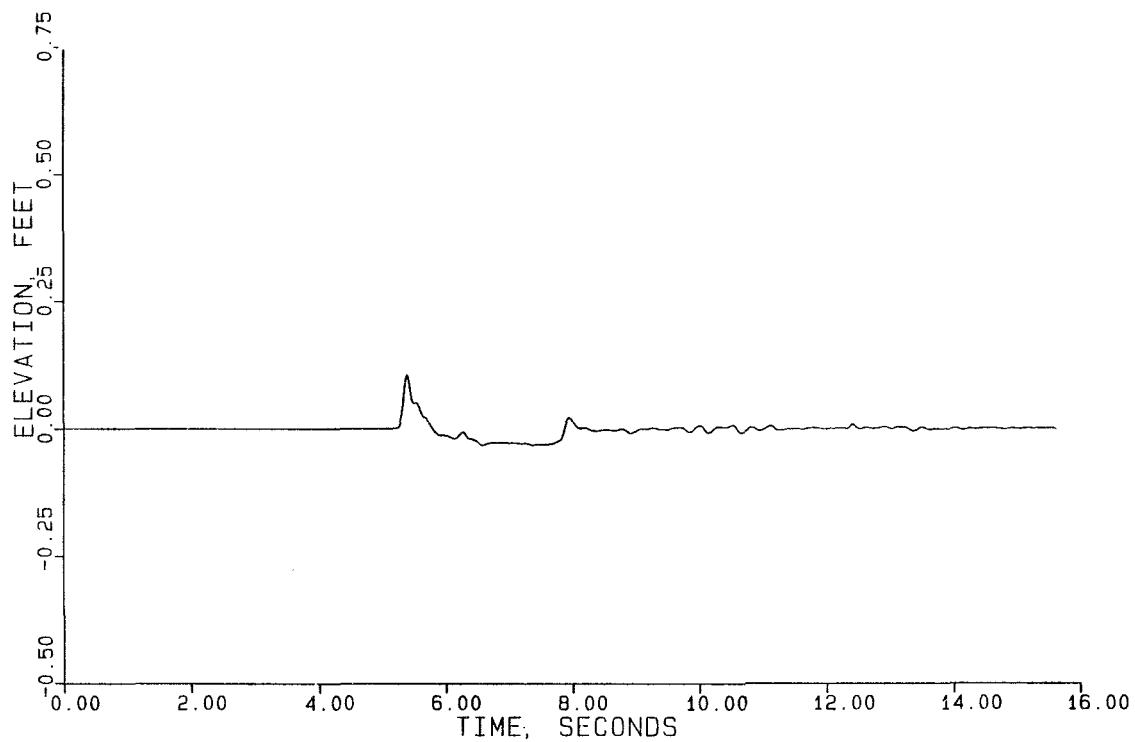
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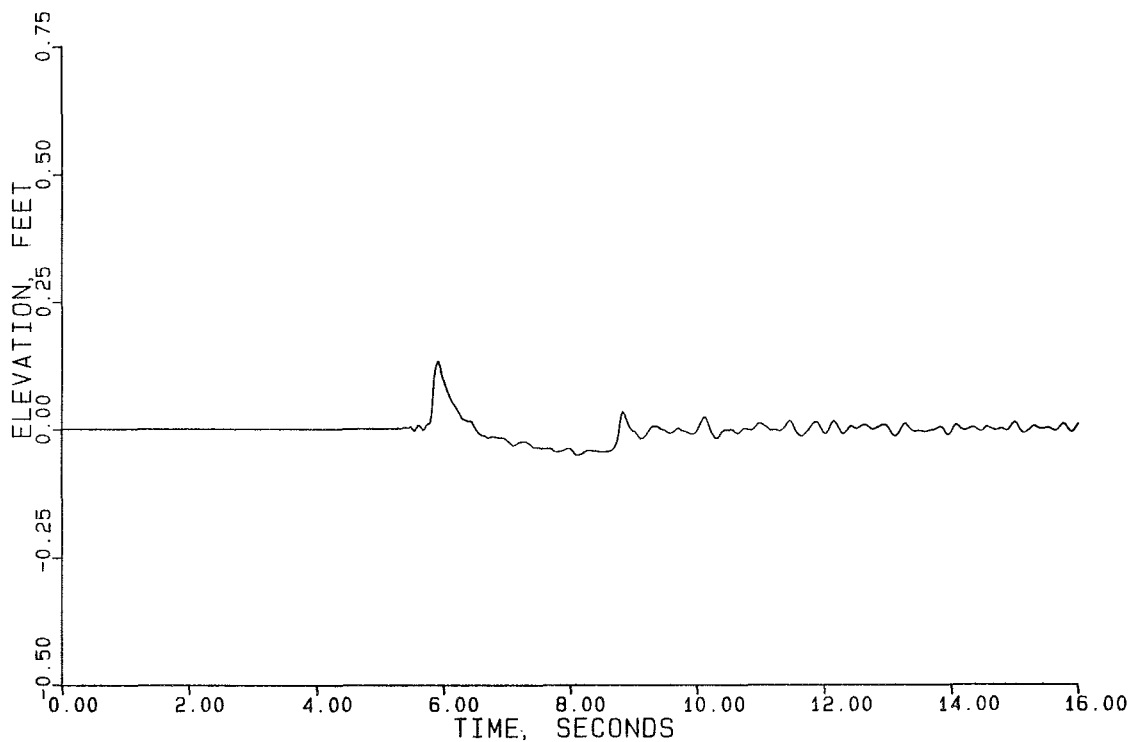
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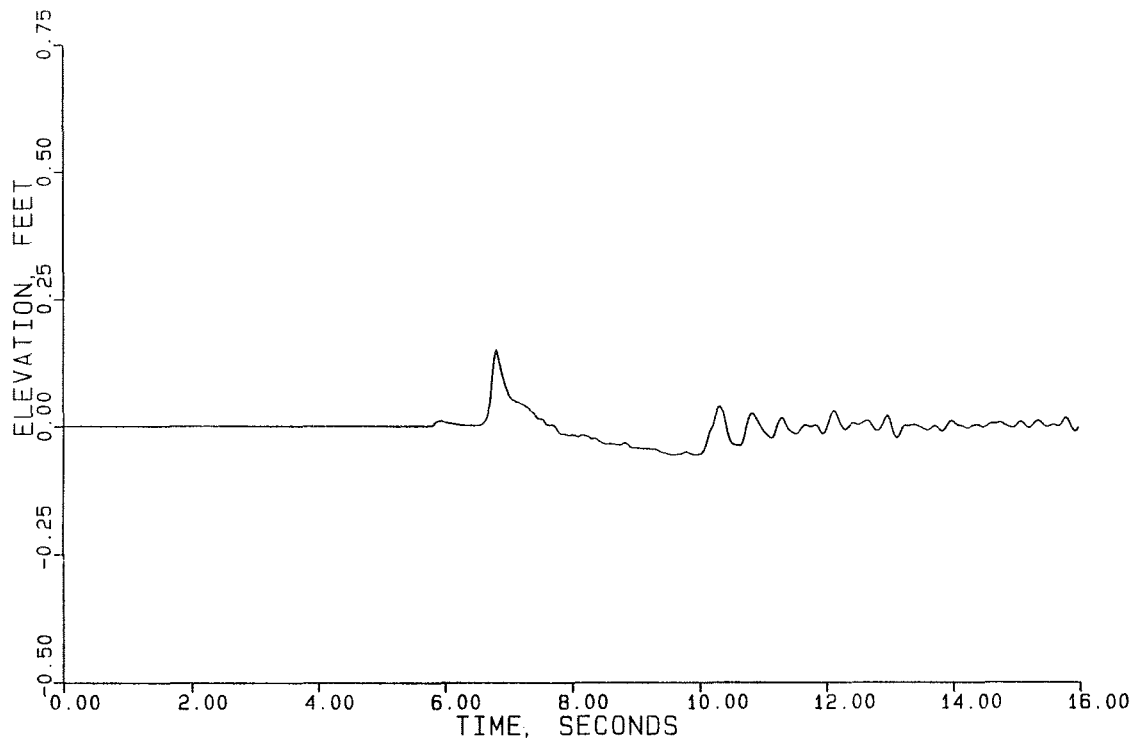
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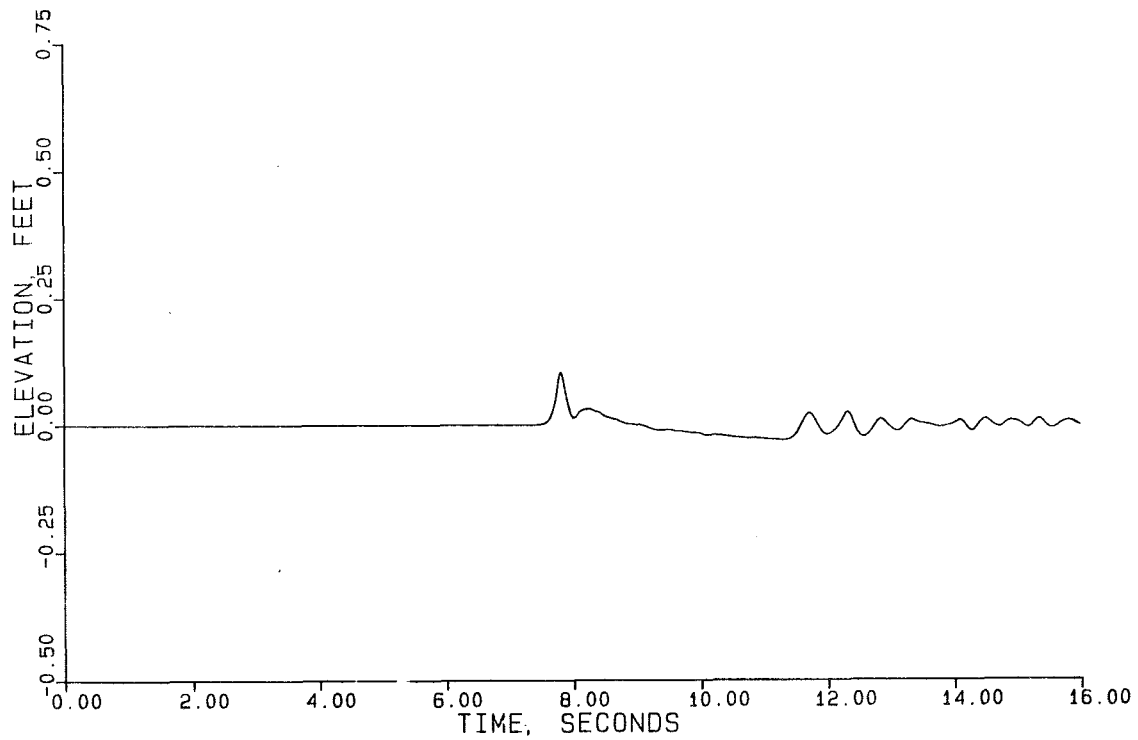
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TEST 1 , GAGE 5



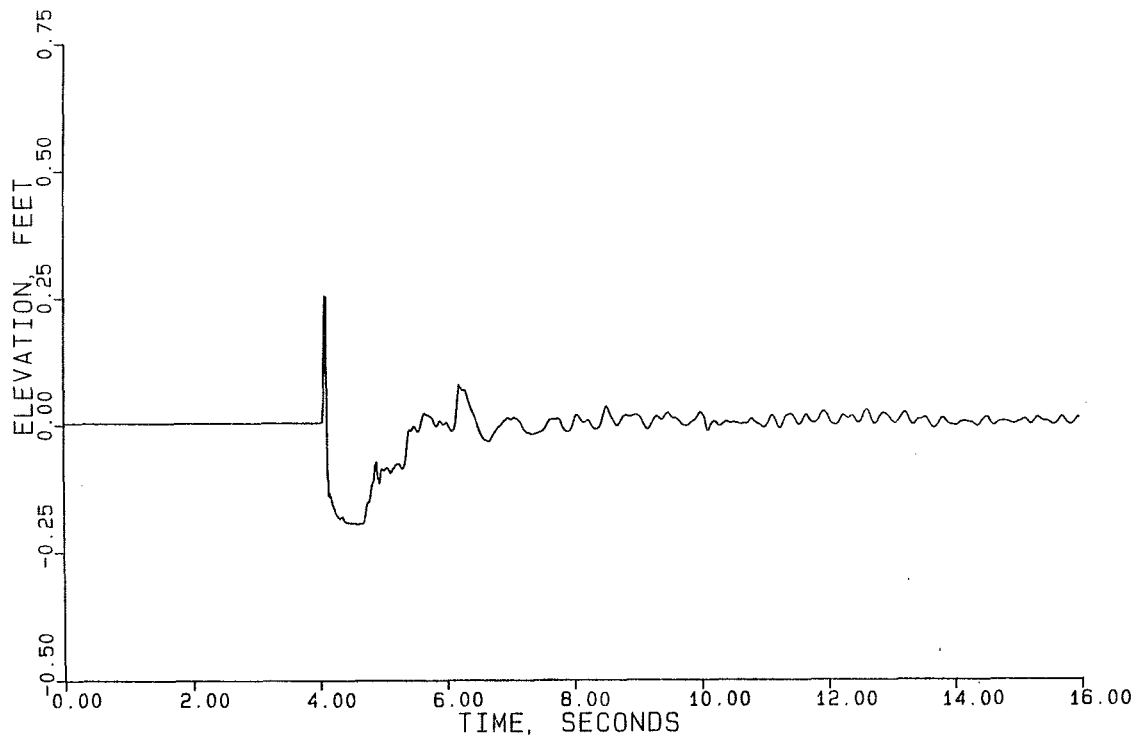
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TEST 1 , GAGE 6



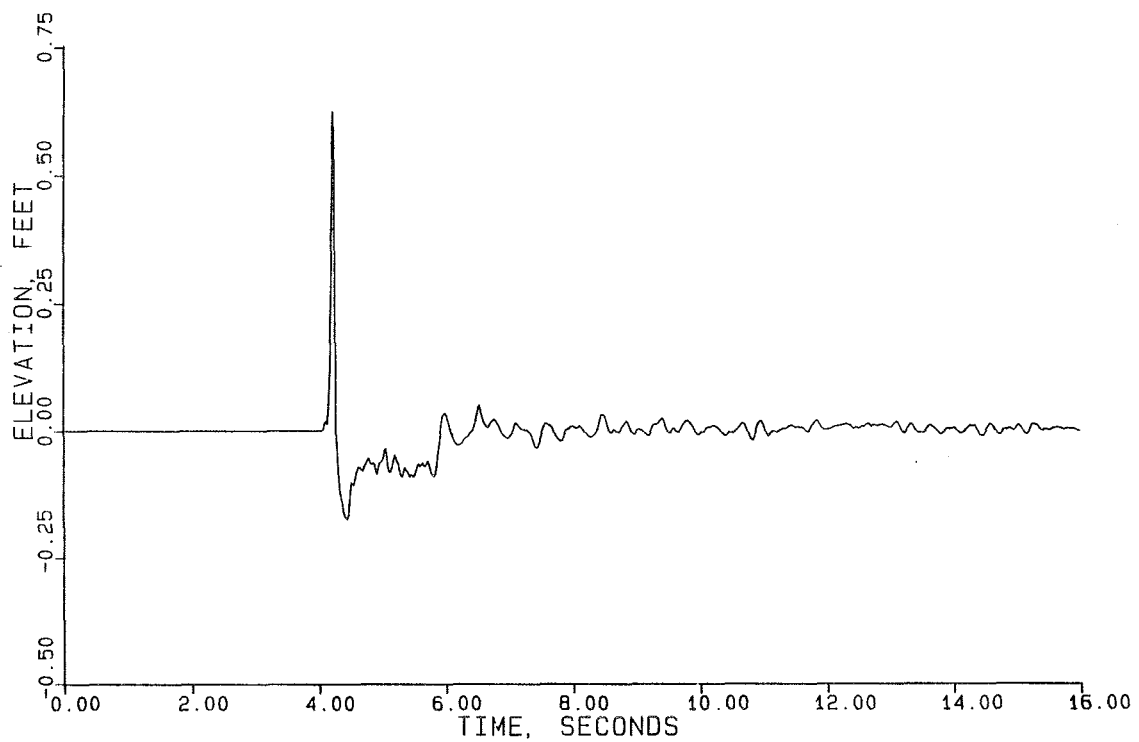
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TEST 1 , GAGE 7



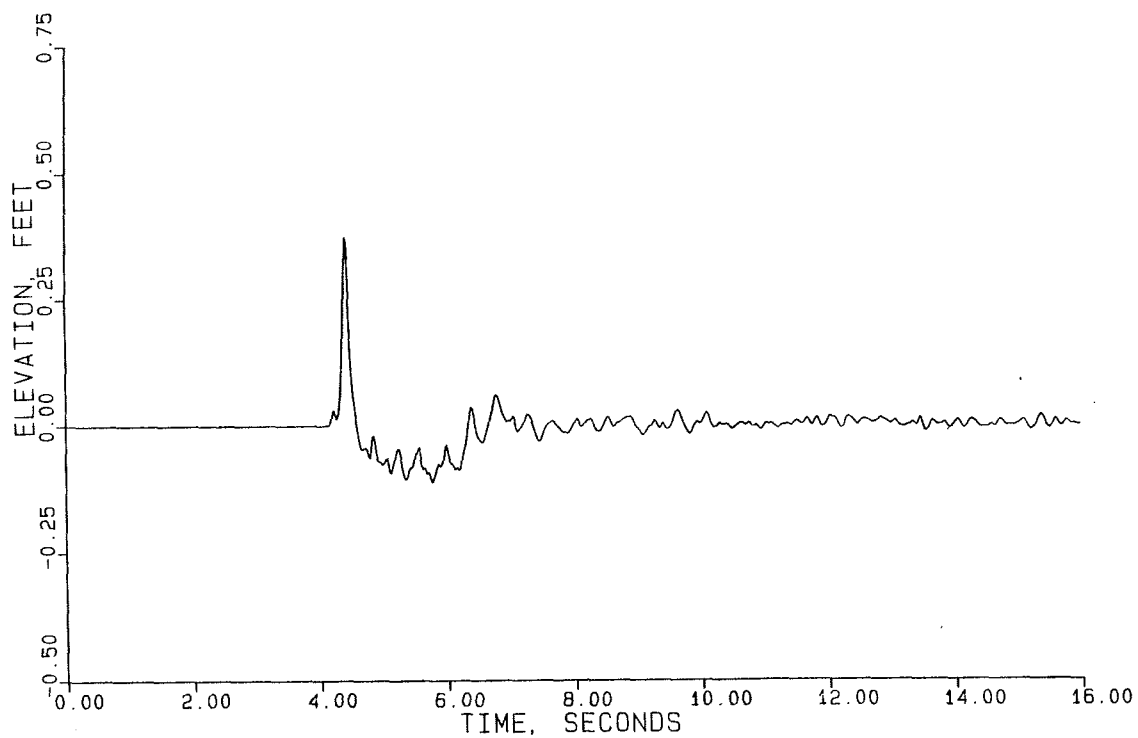
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TEST 1 , GAGE 8



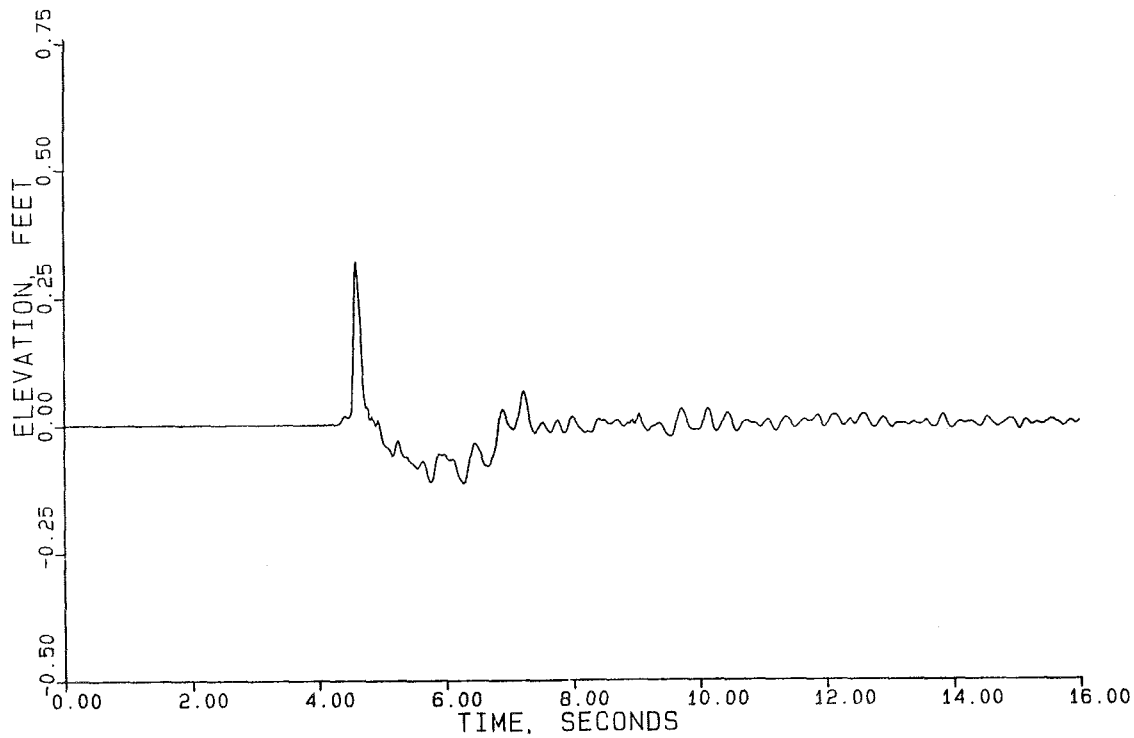
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TEST 2 , GAGE 1



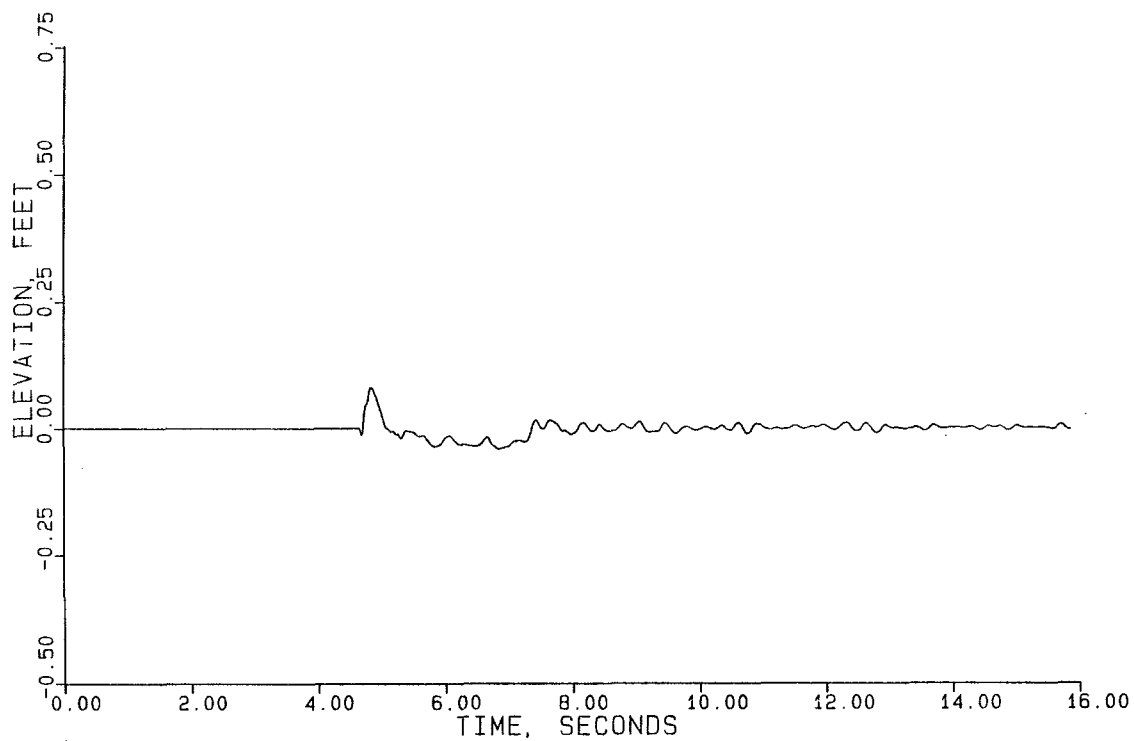
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TEST 2 , GAGE 2



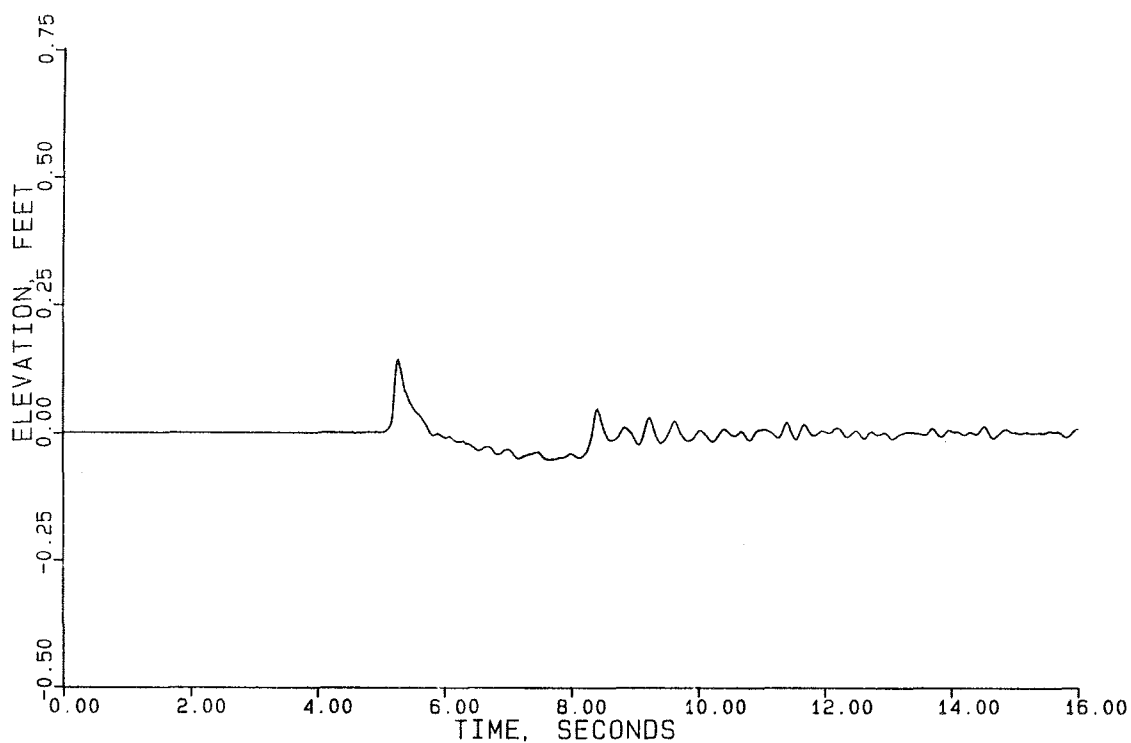
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TEST 2 , GAGE 3



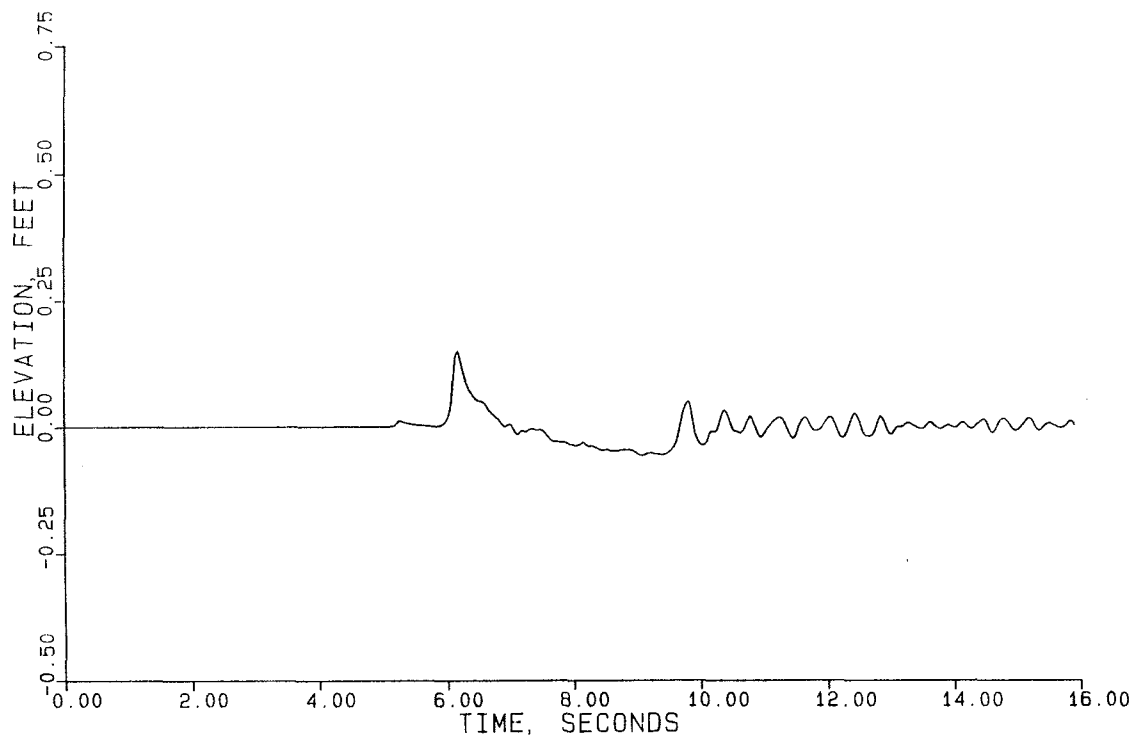
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TEST 2 , GAGE 4



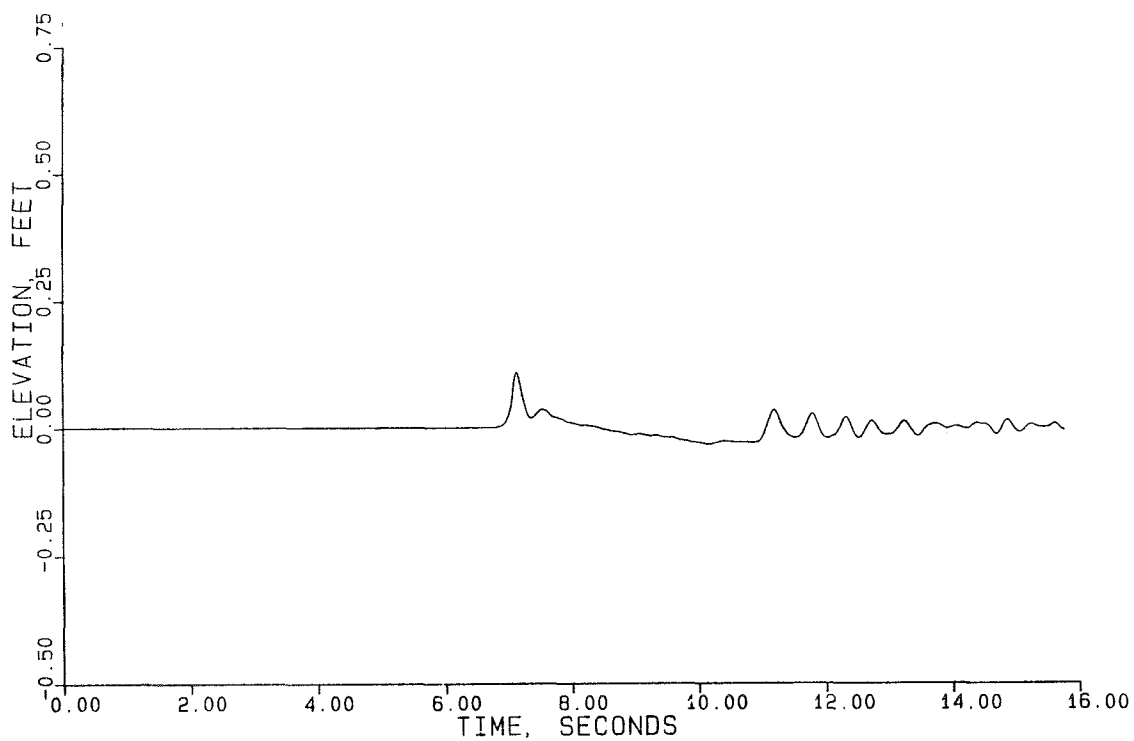
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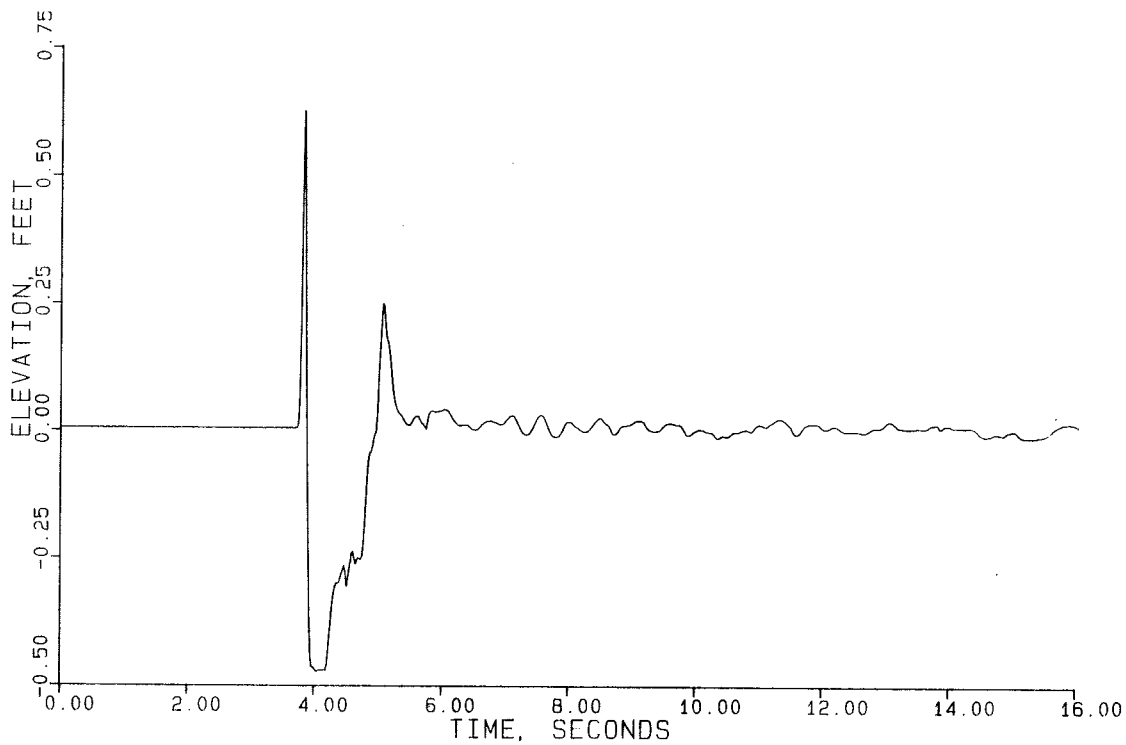


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TEST 2 , GAGE 7

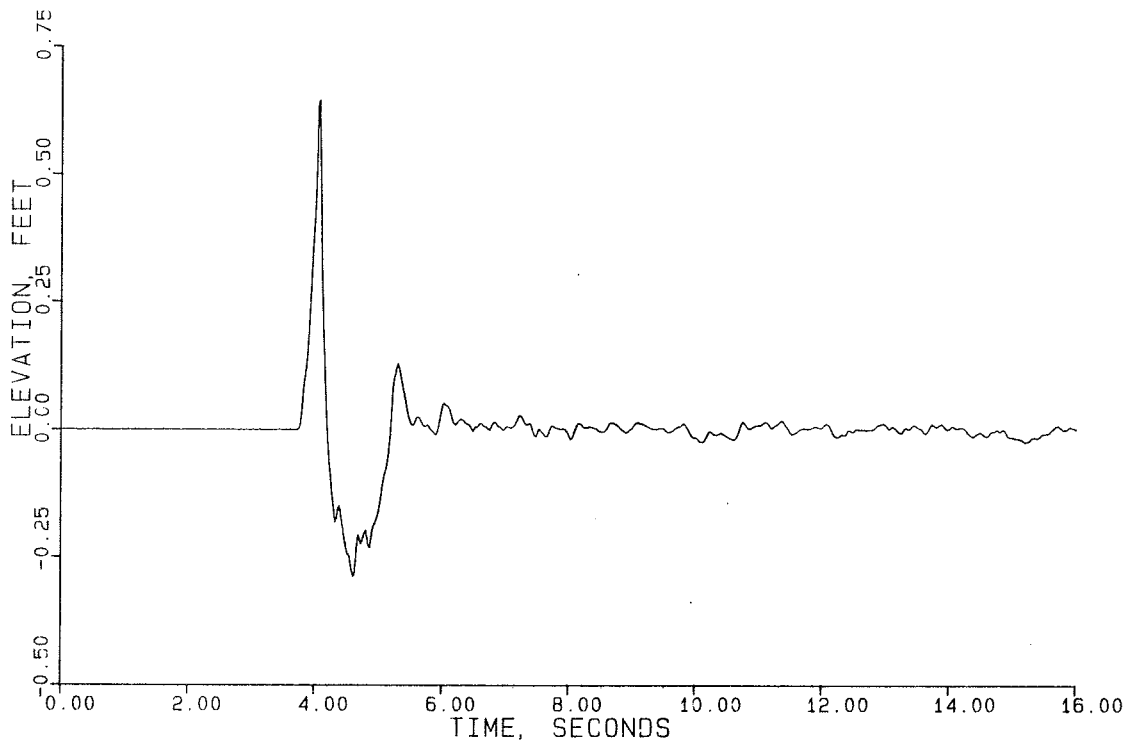


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TEST 2 , GAGE 8

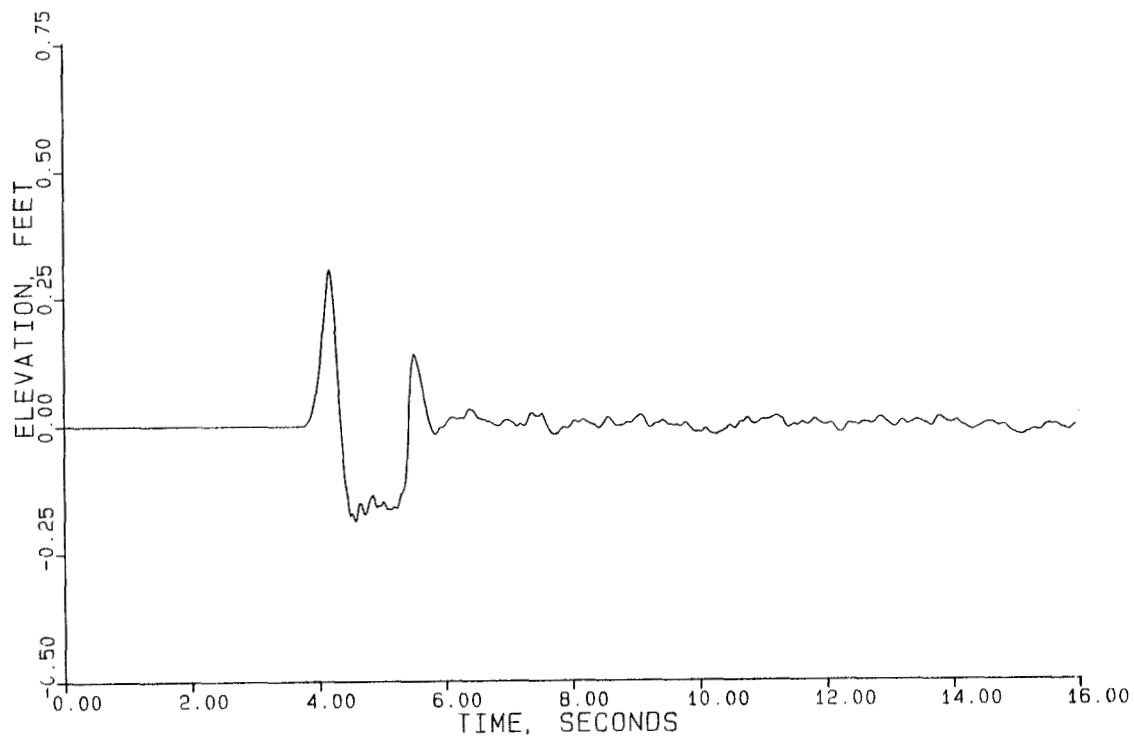




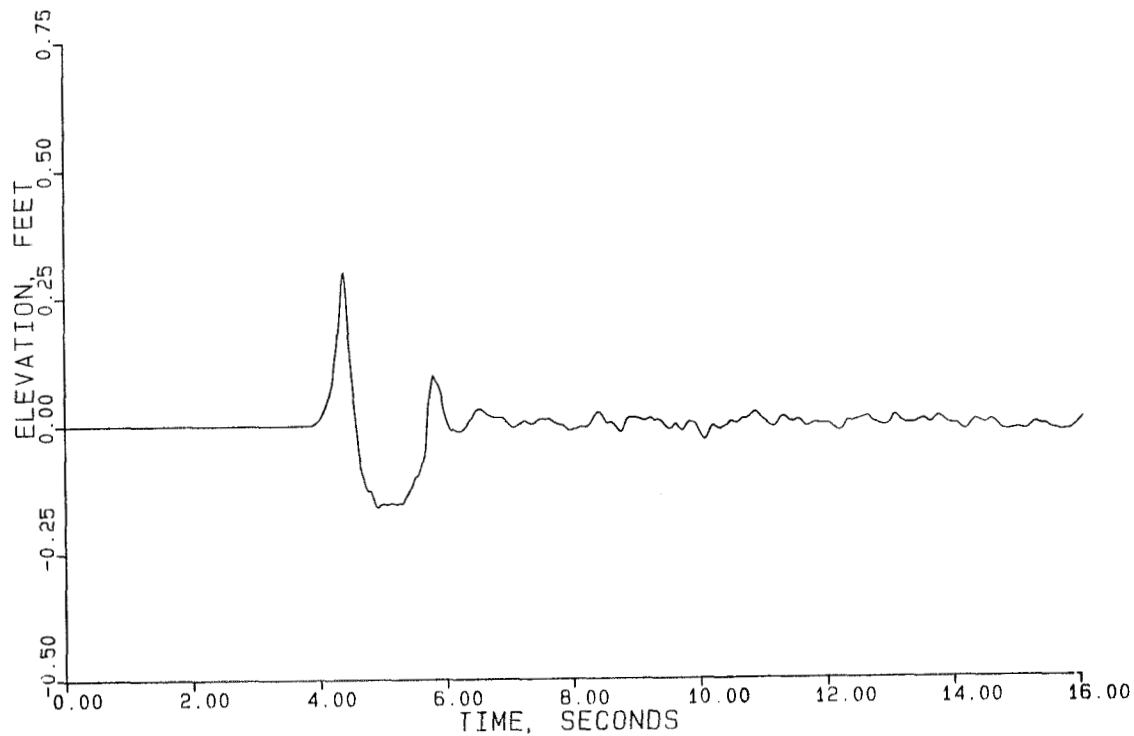
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TEST 3 , GAGE 1



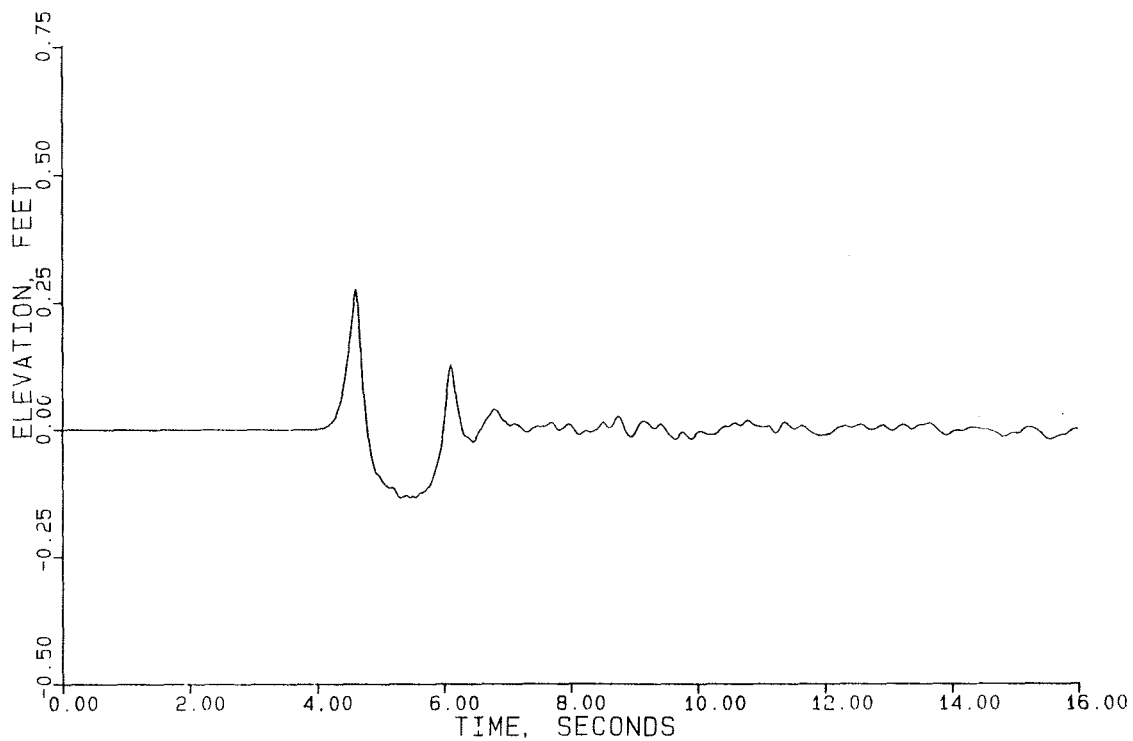
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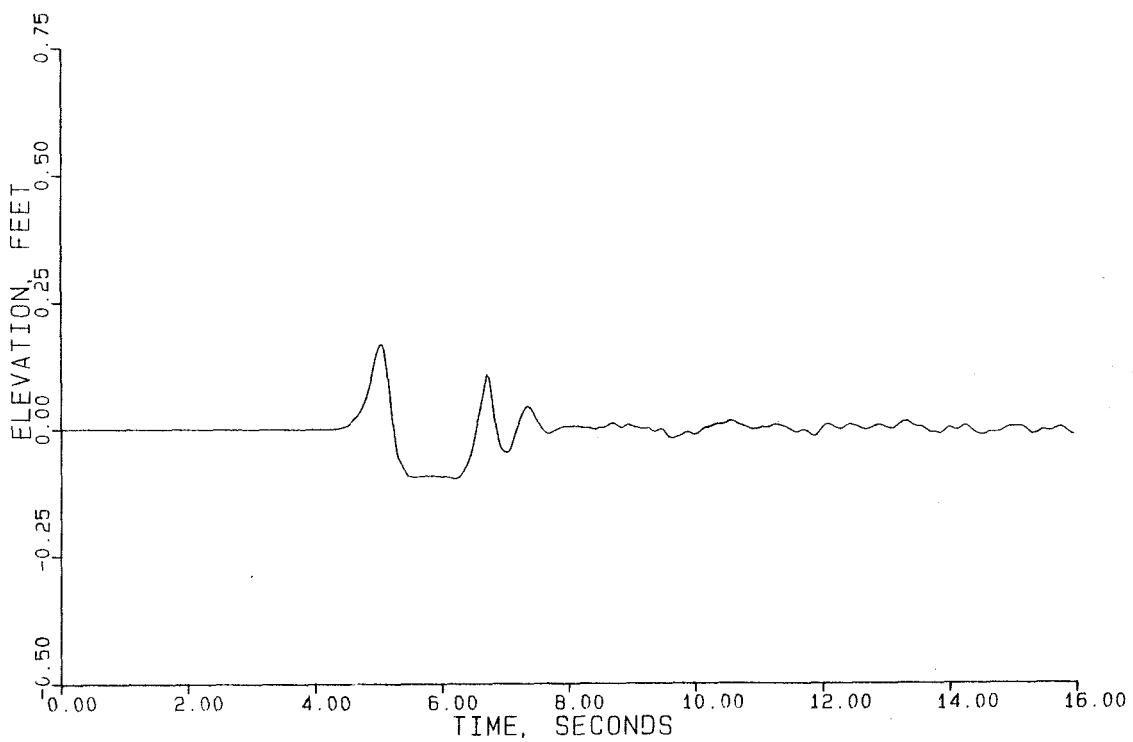
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TEST 3 , GAGE 3



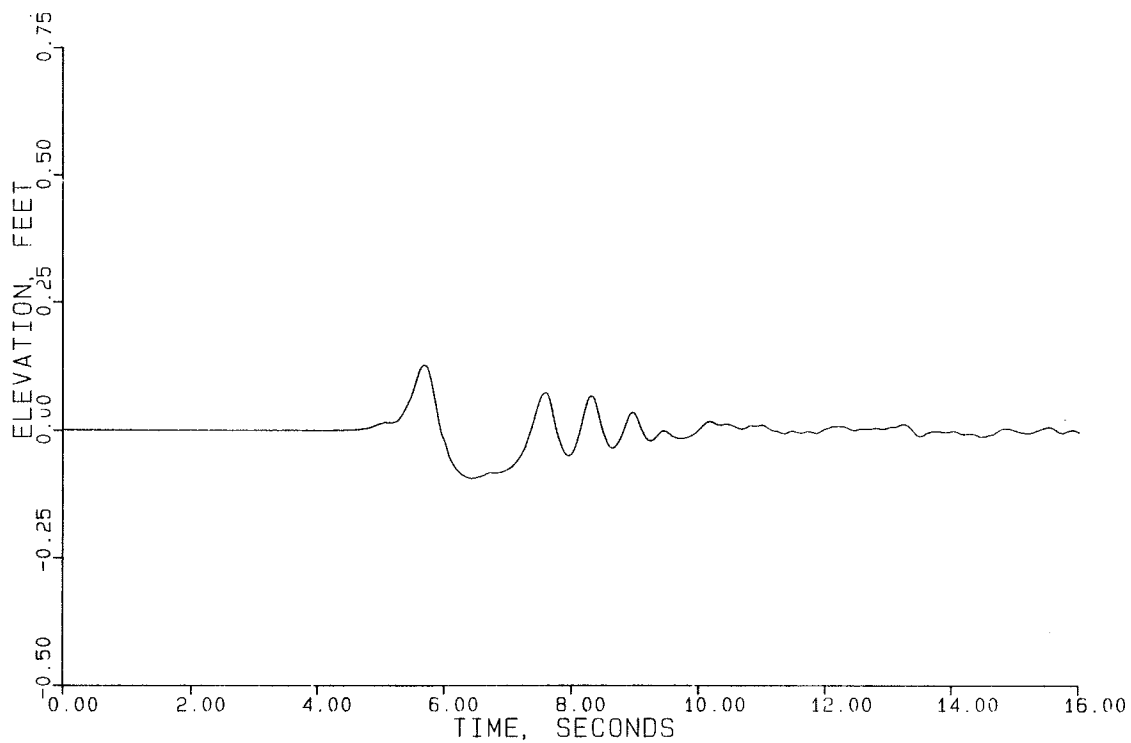
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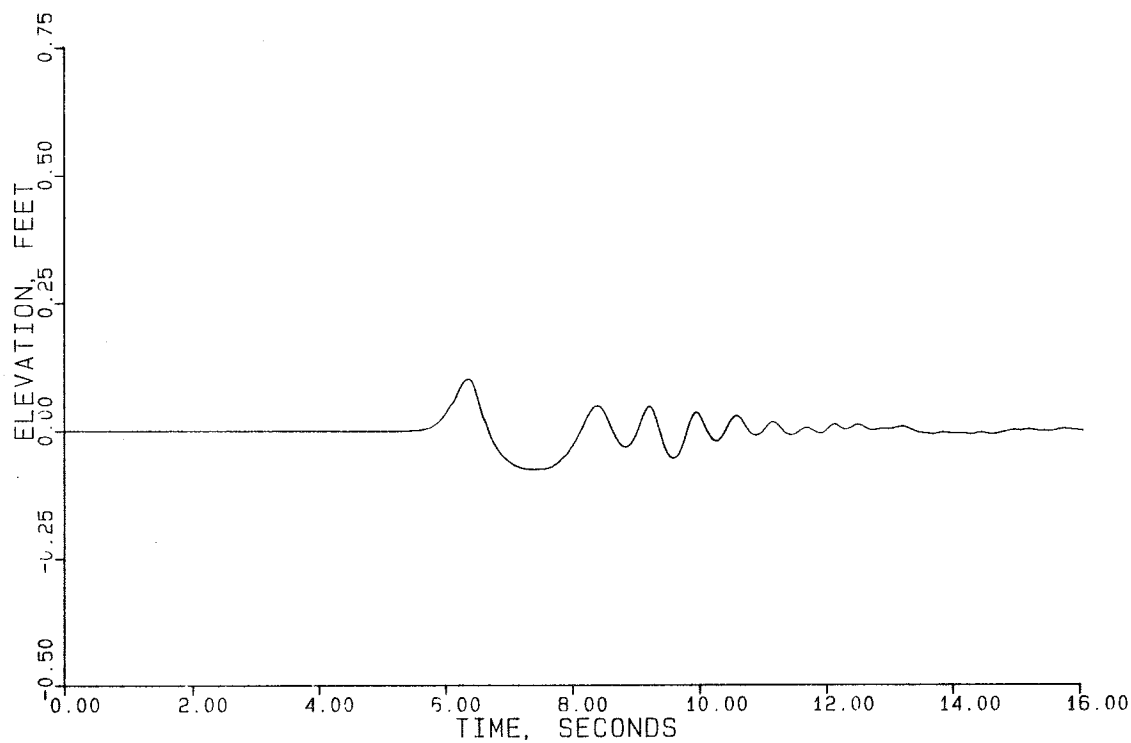
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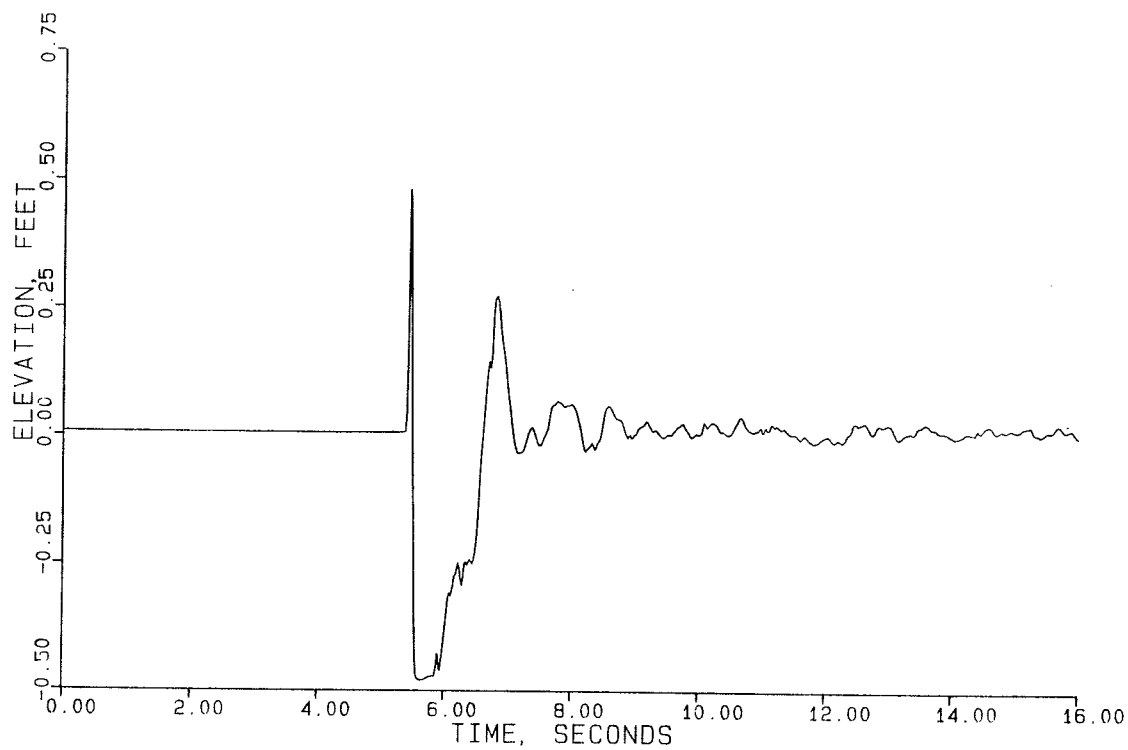
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TEST 3 , GAGE 6



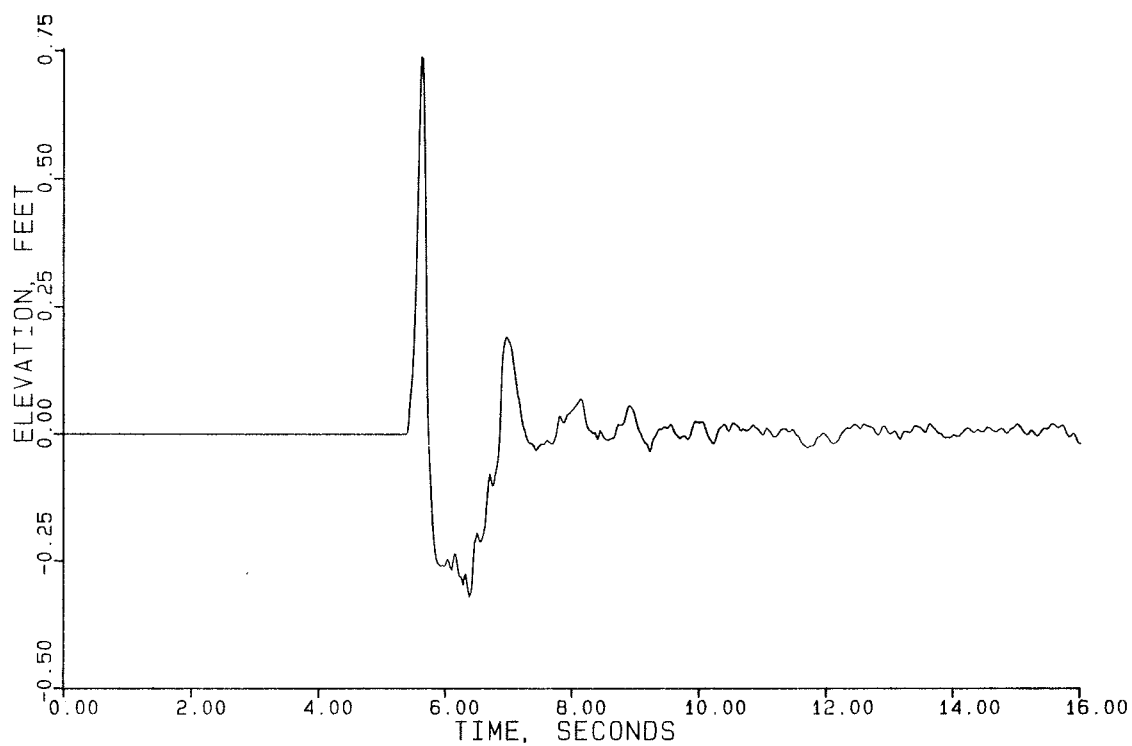
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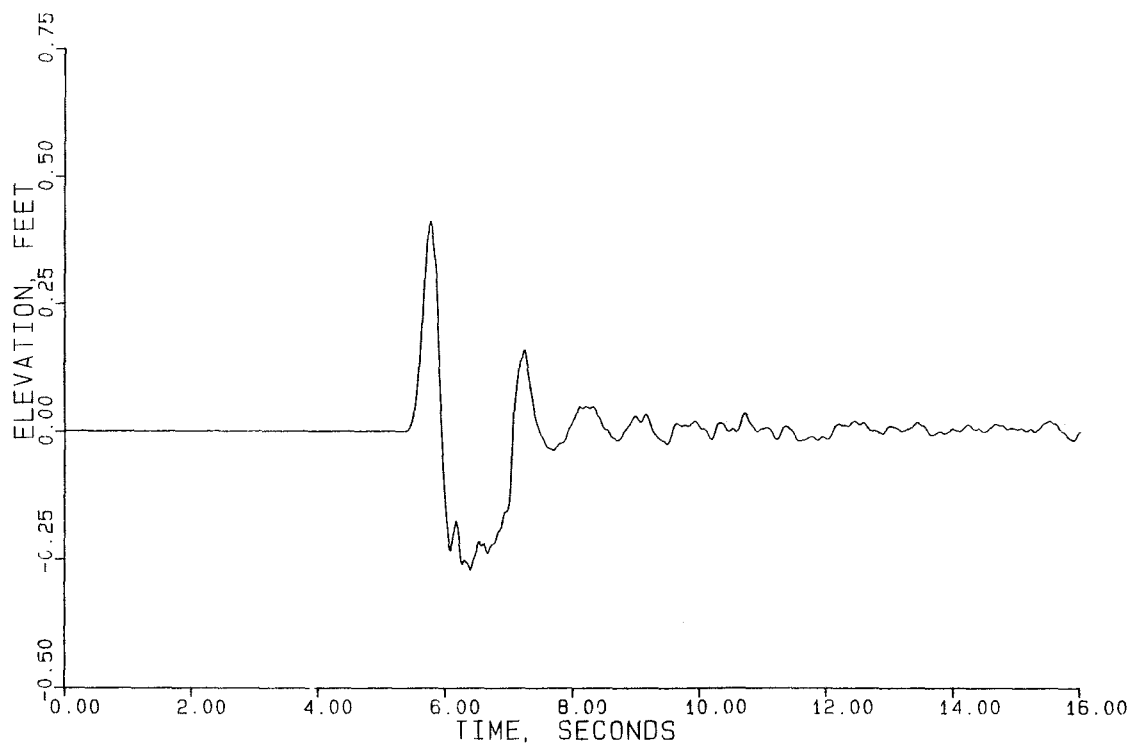
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TEST 3 , GAGE 8



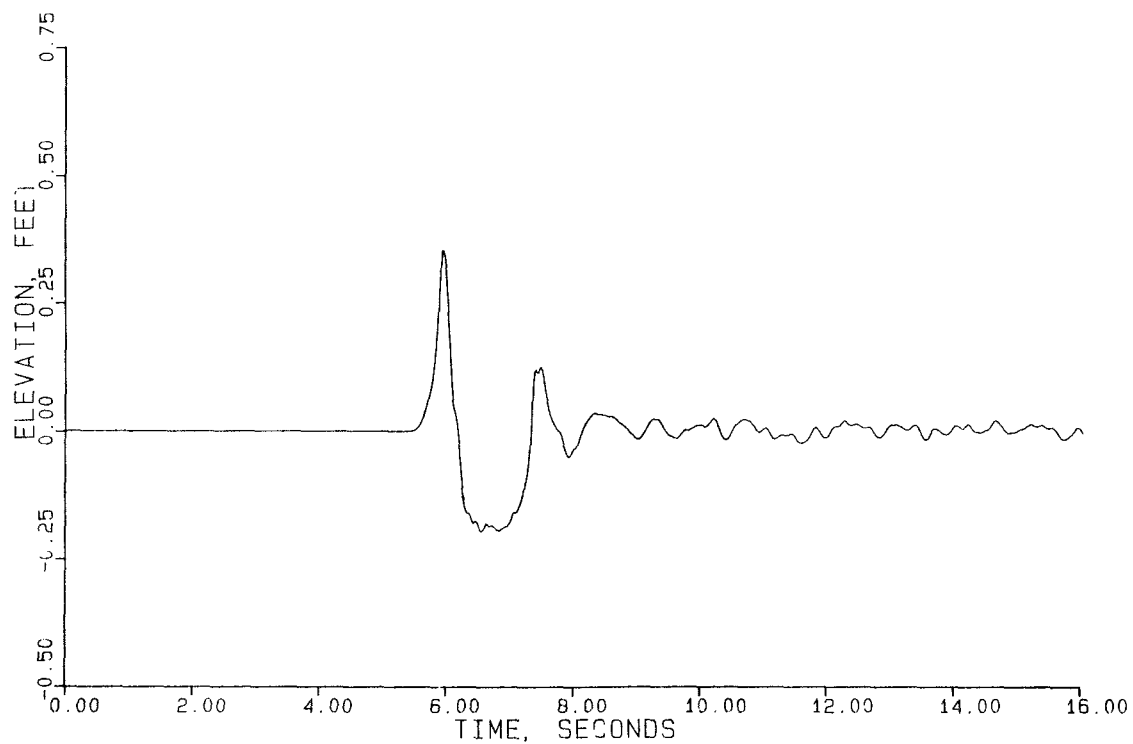
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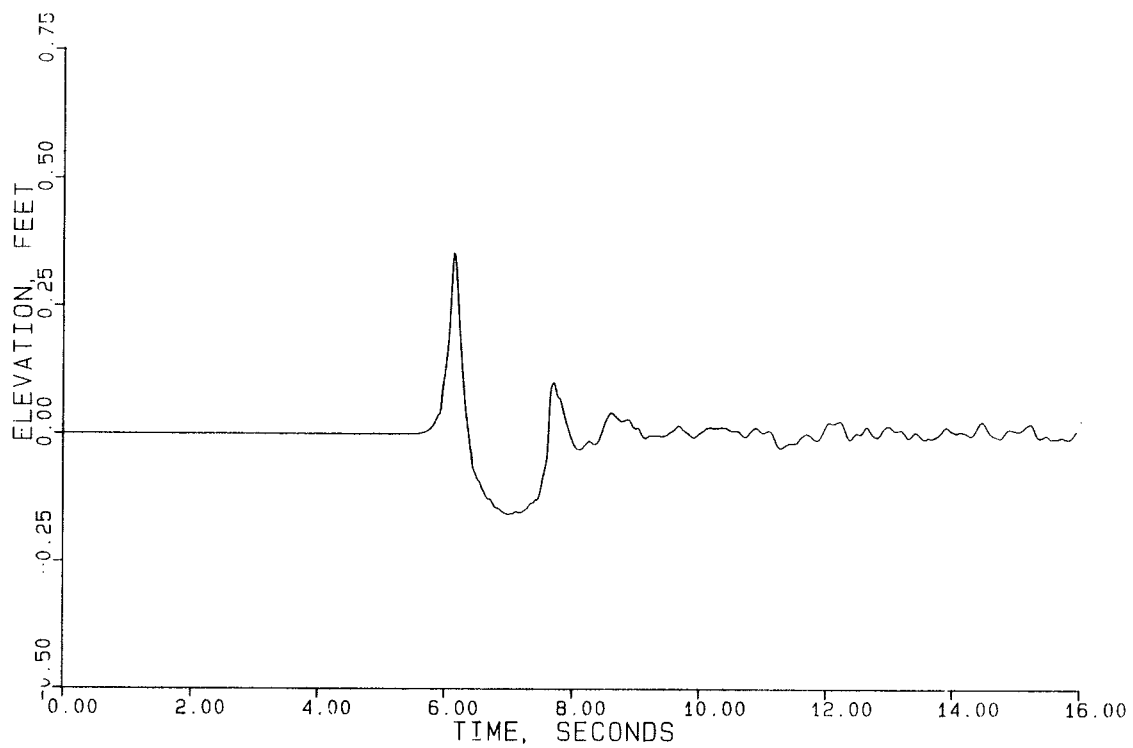
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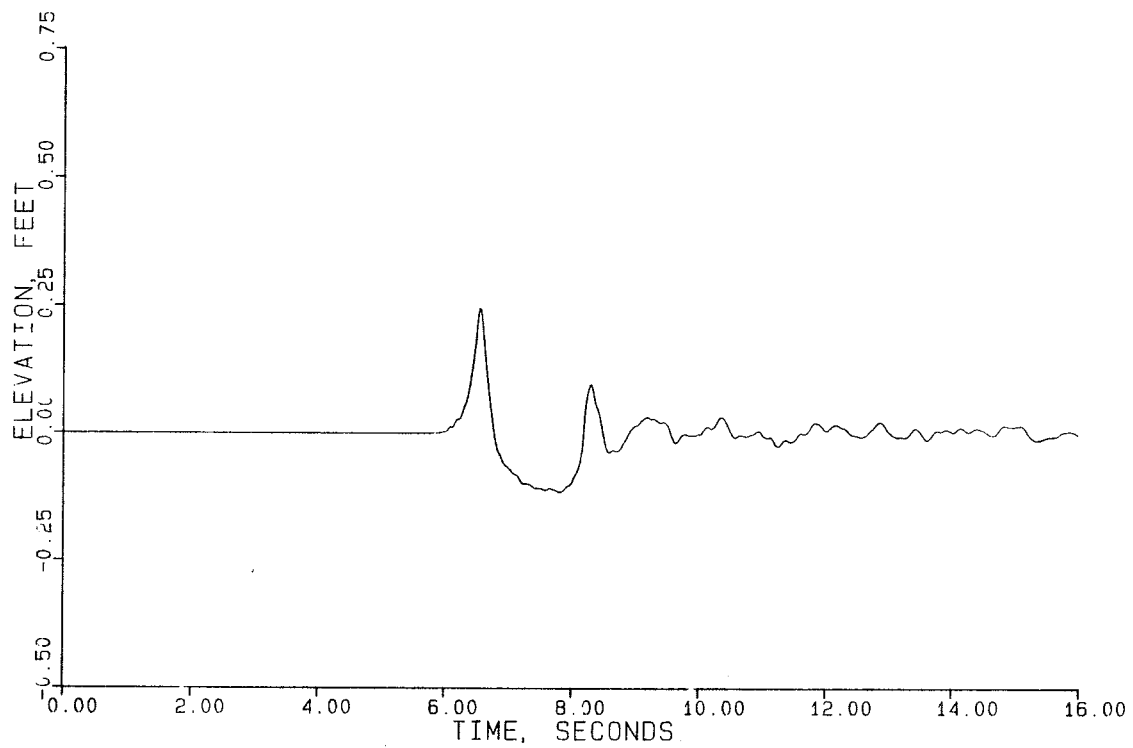
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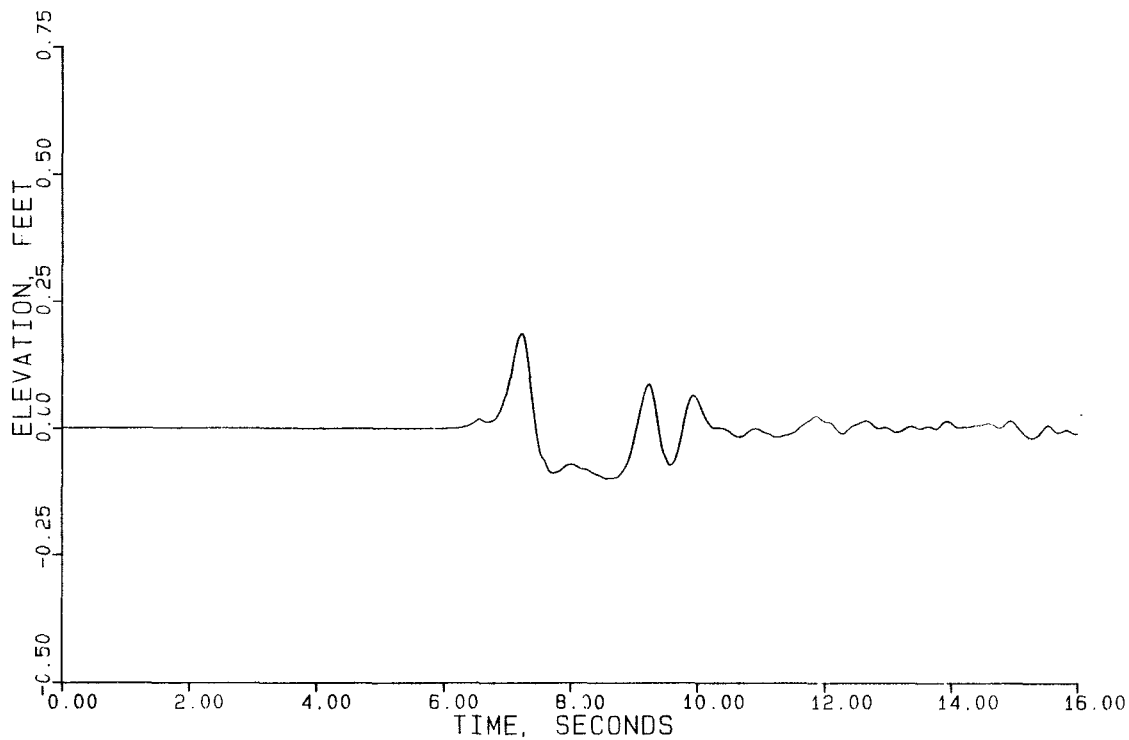
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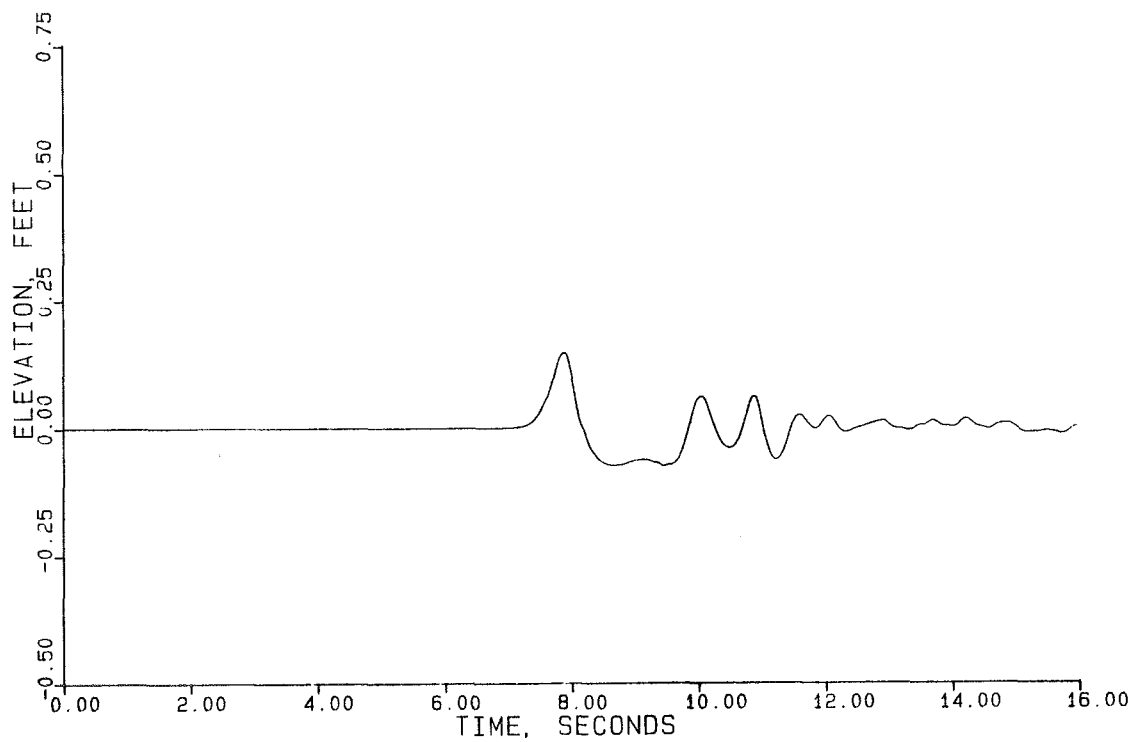
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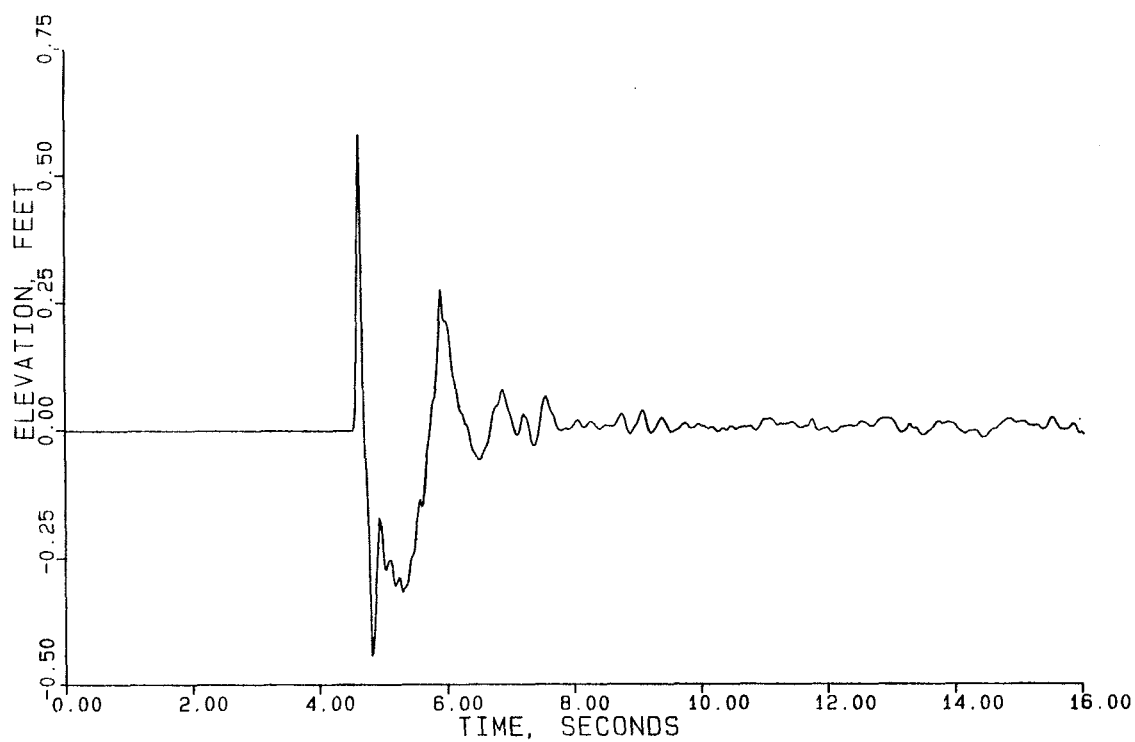


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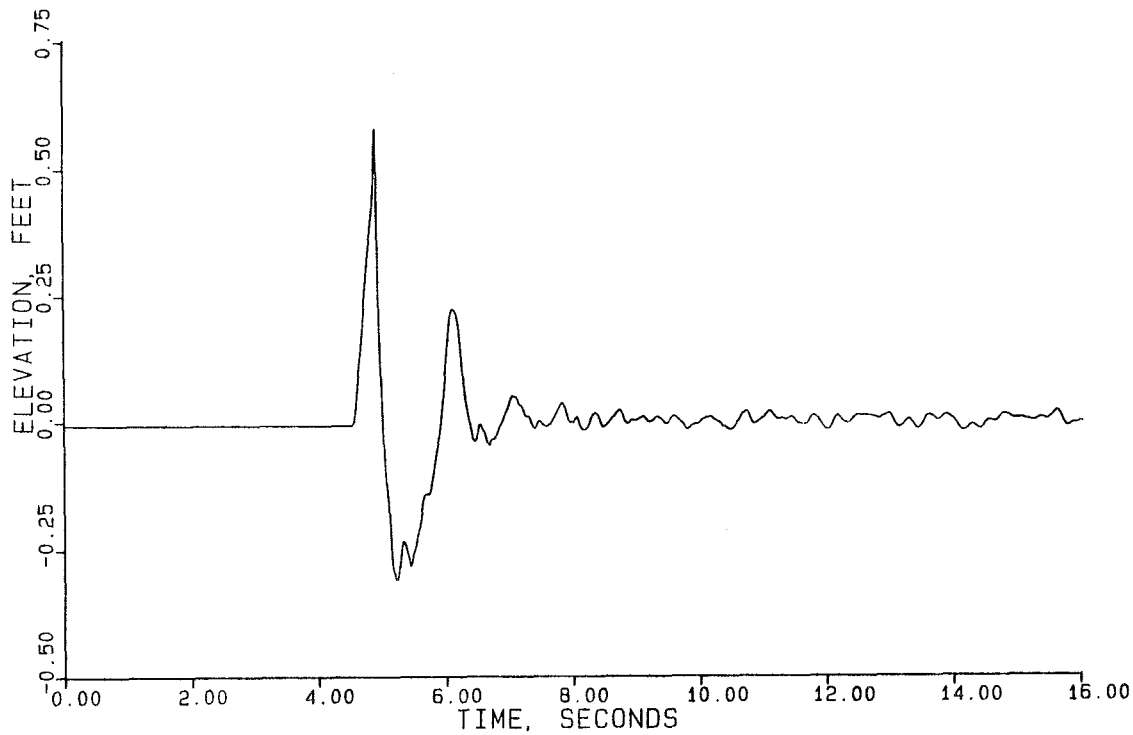


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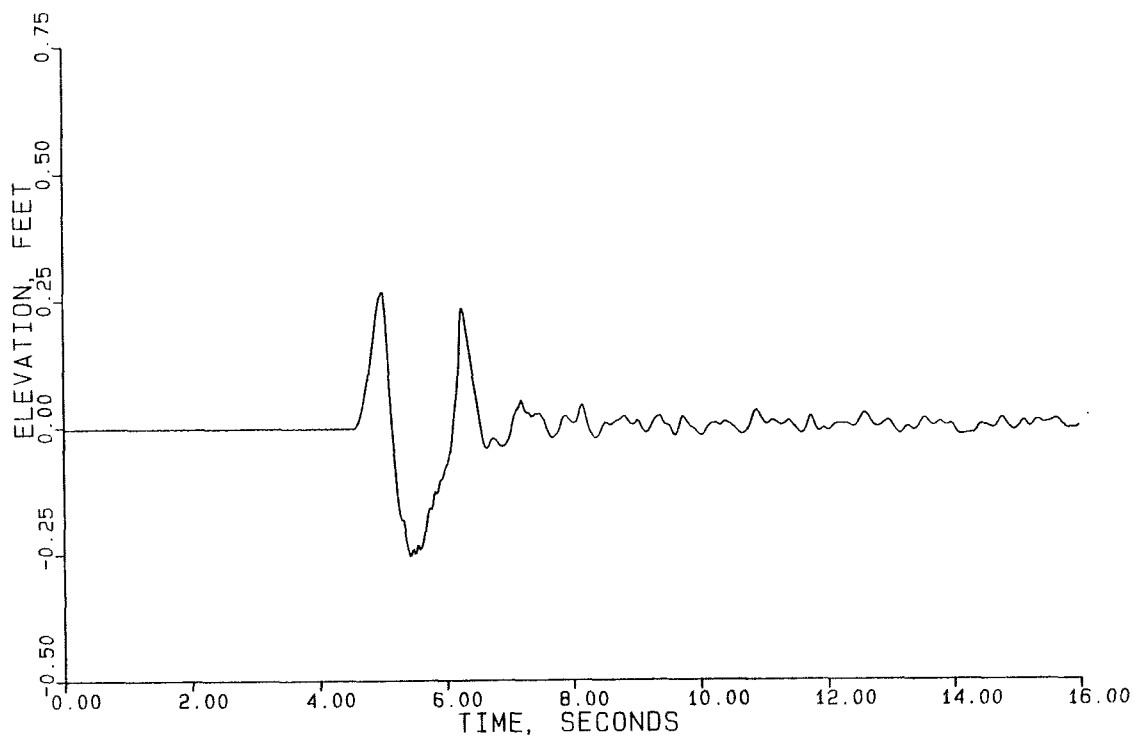




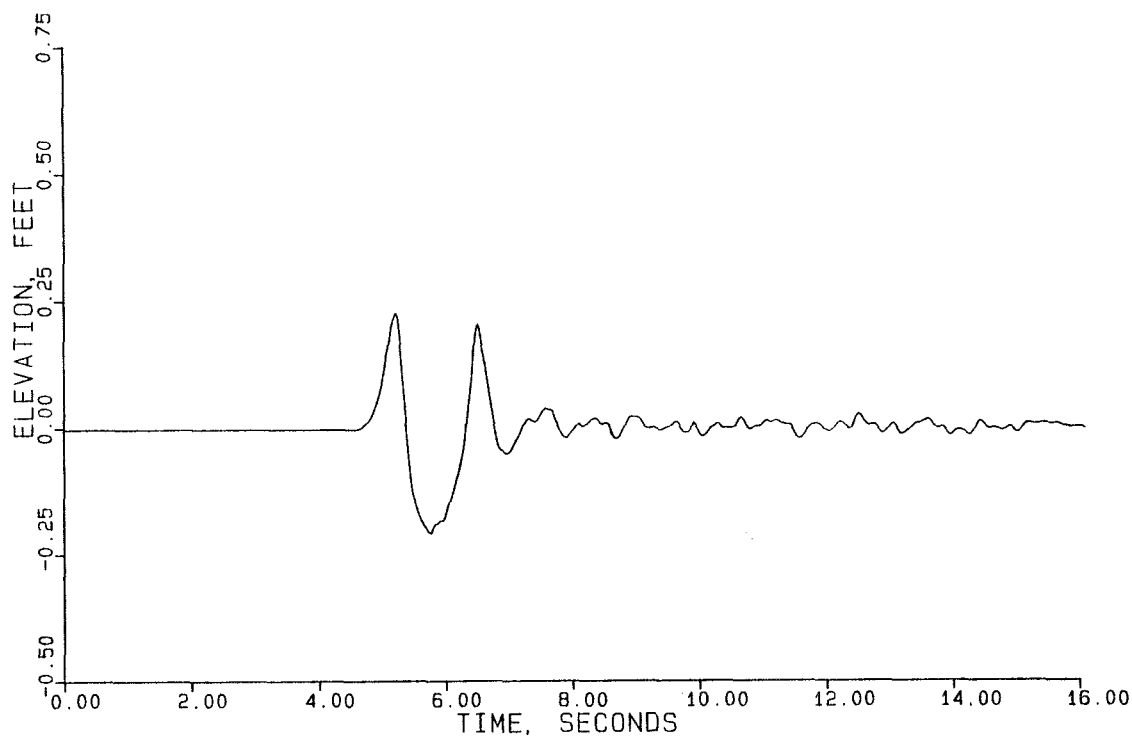
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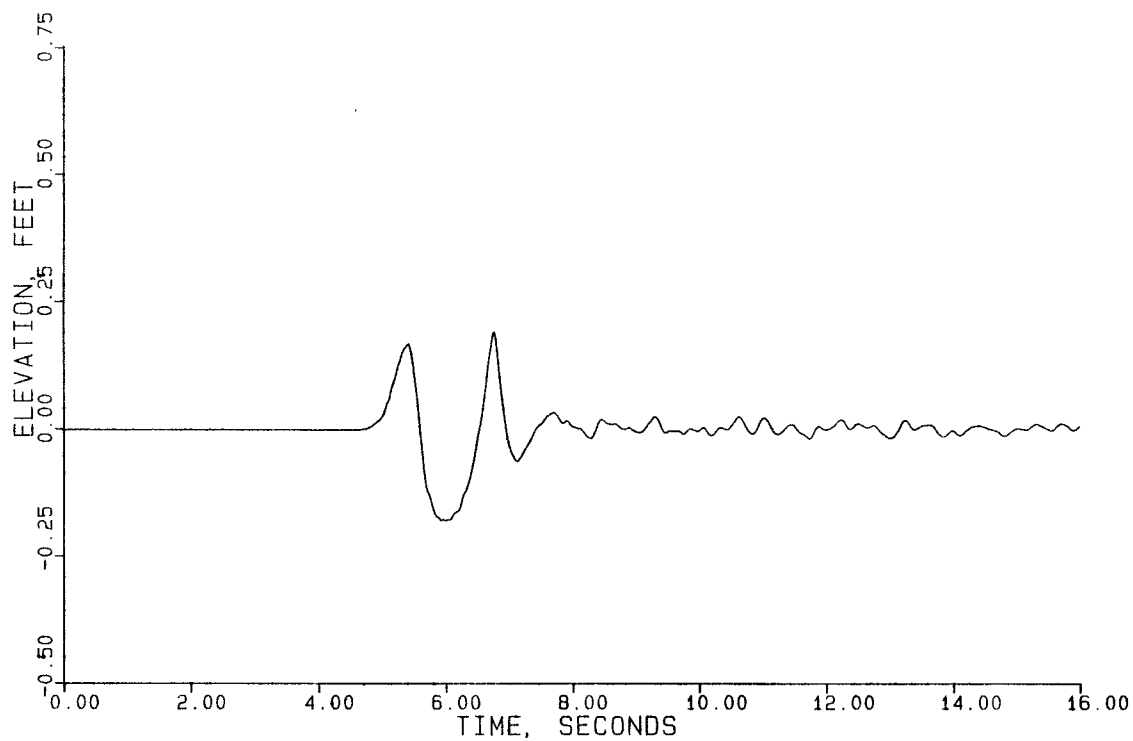
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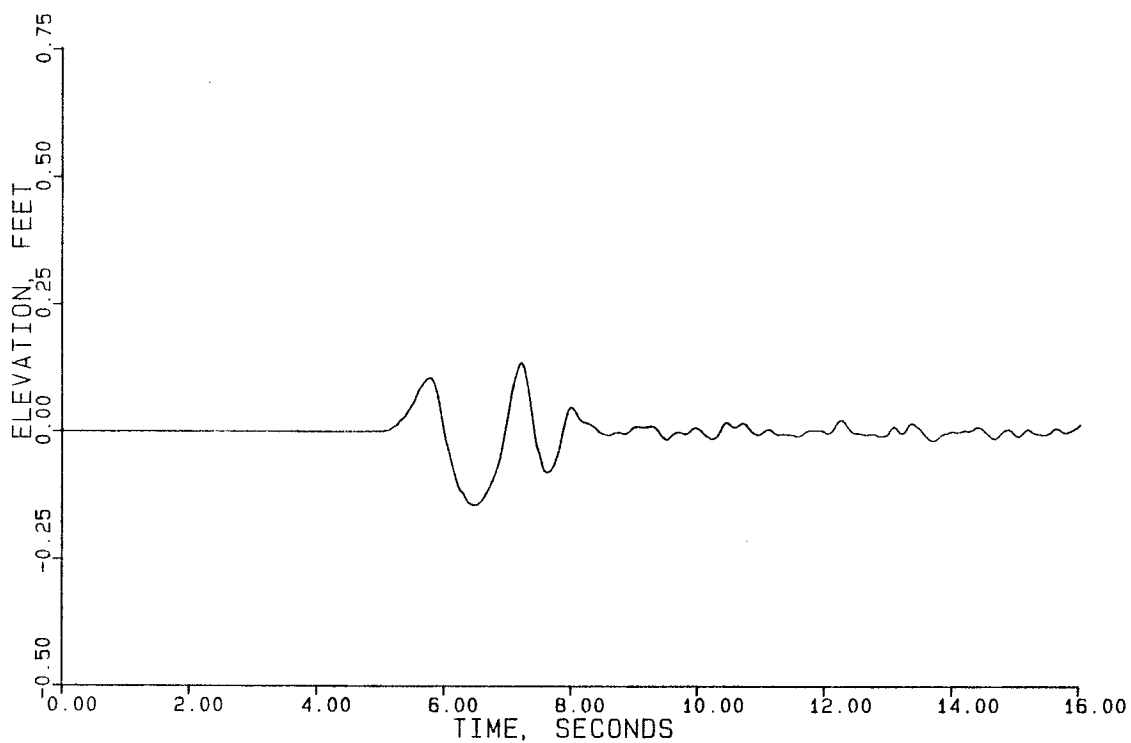
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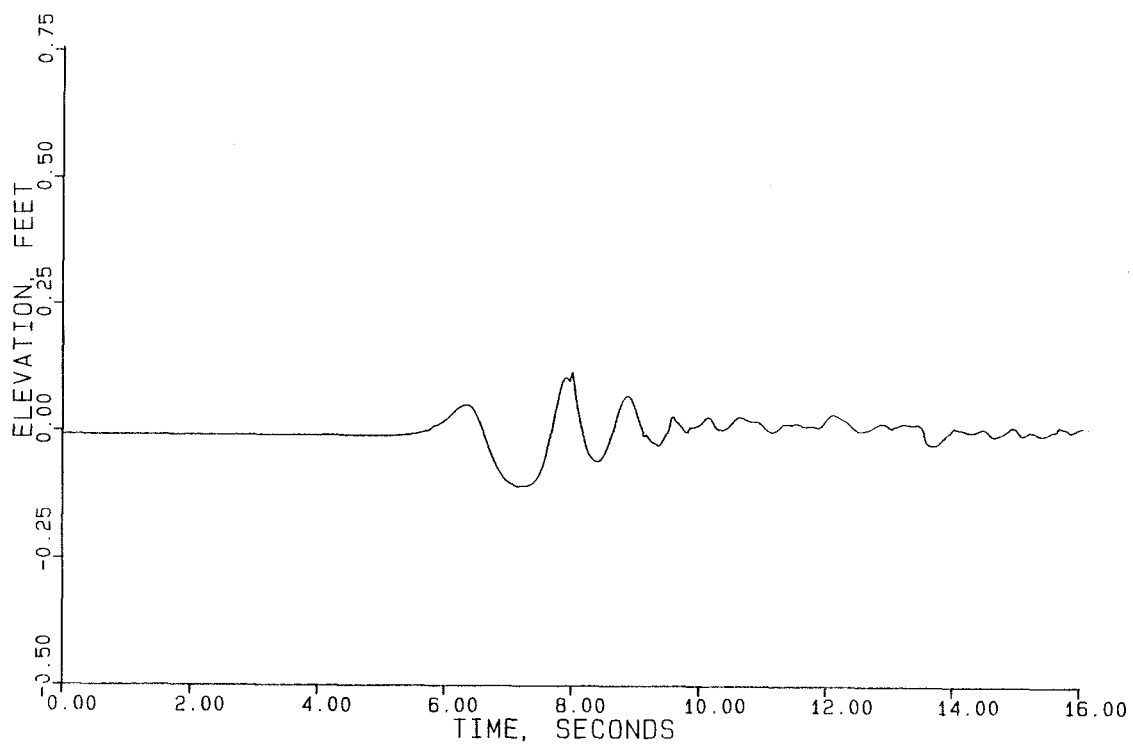
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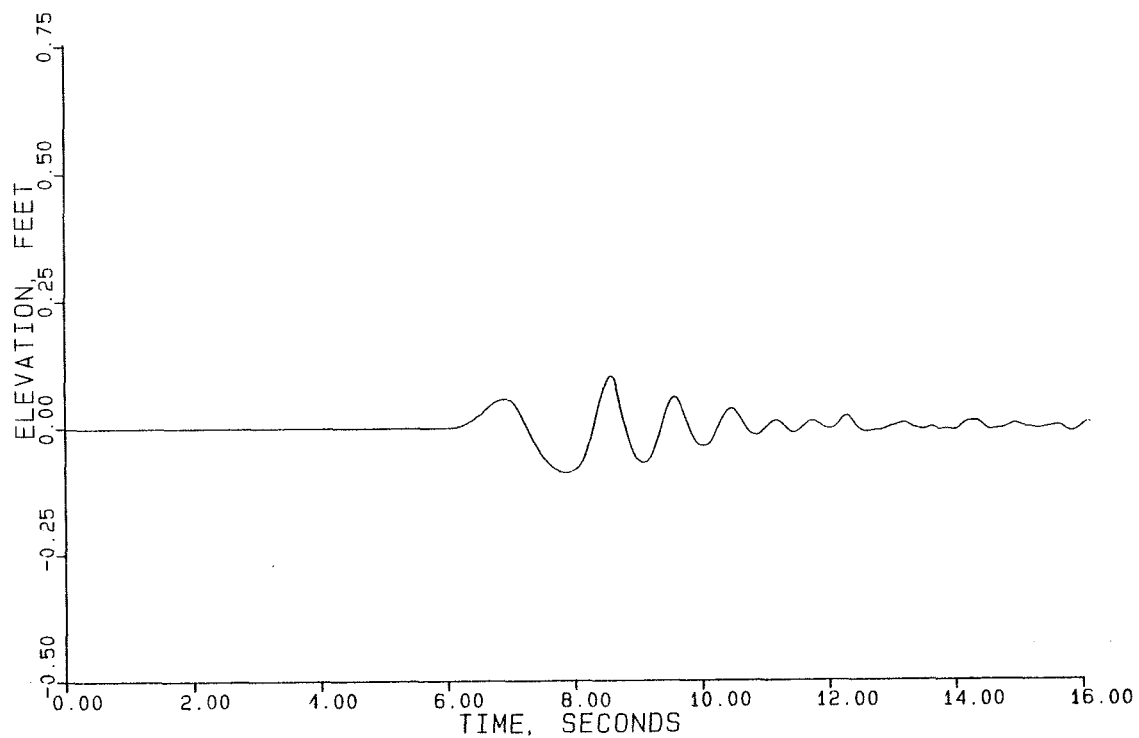
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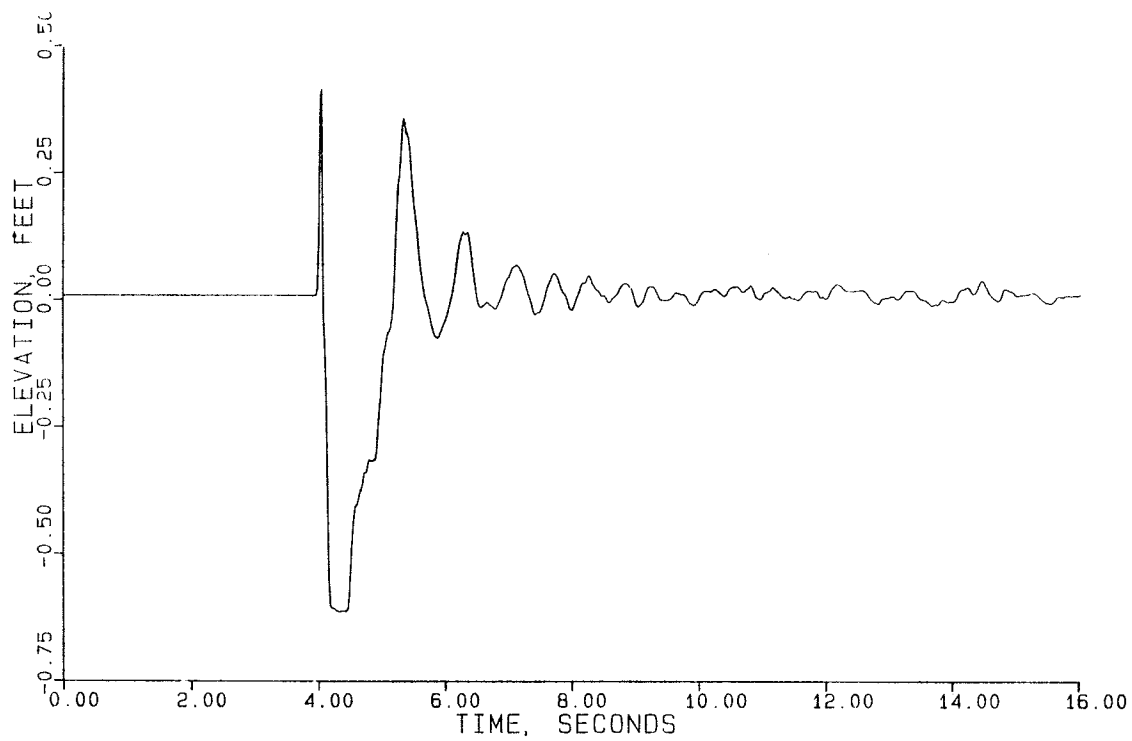
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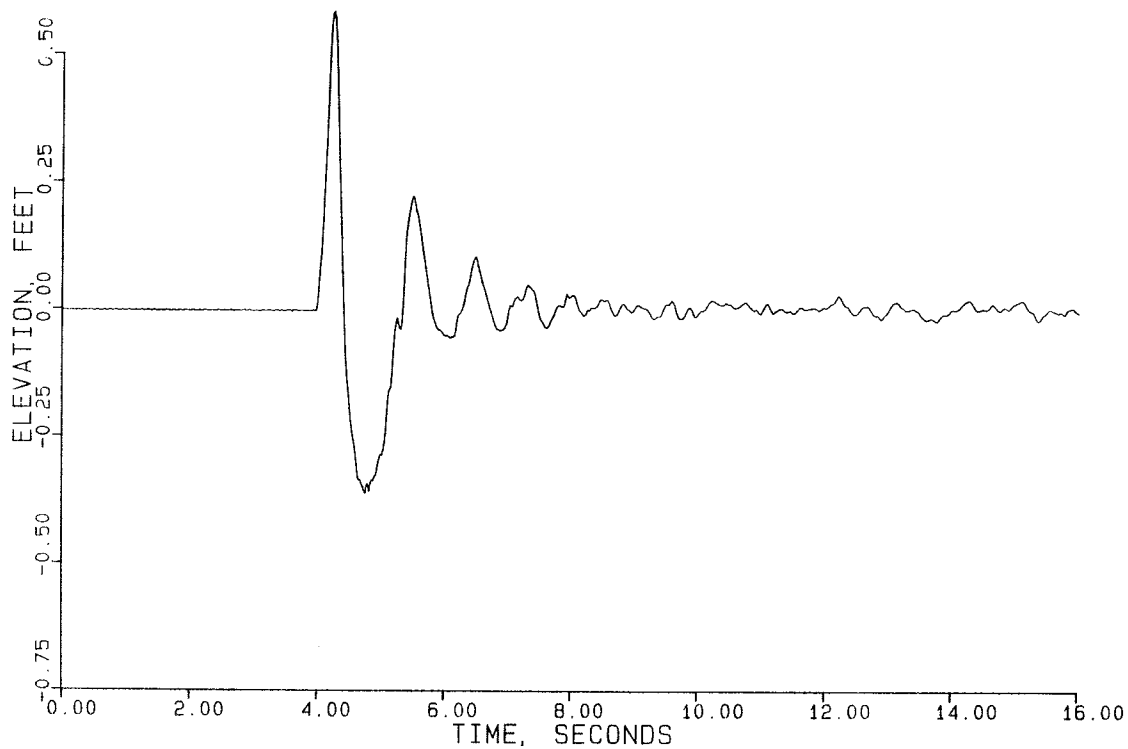
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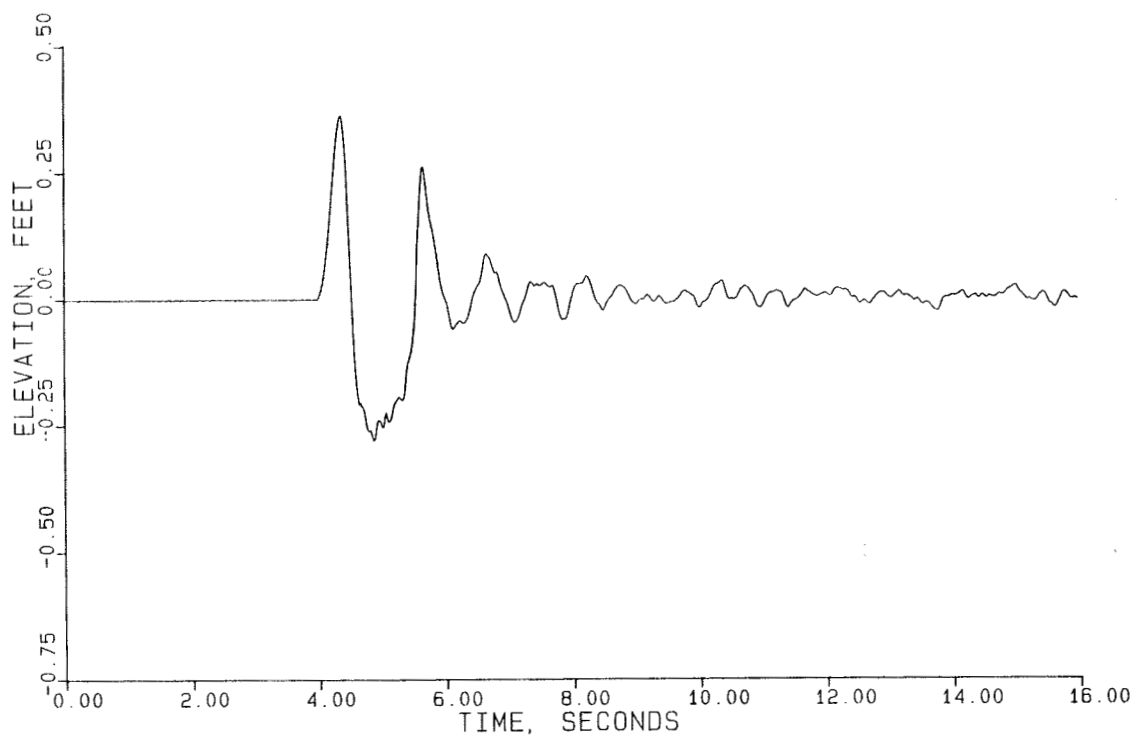
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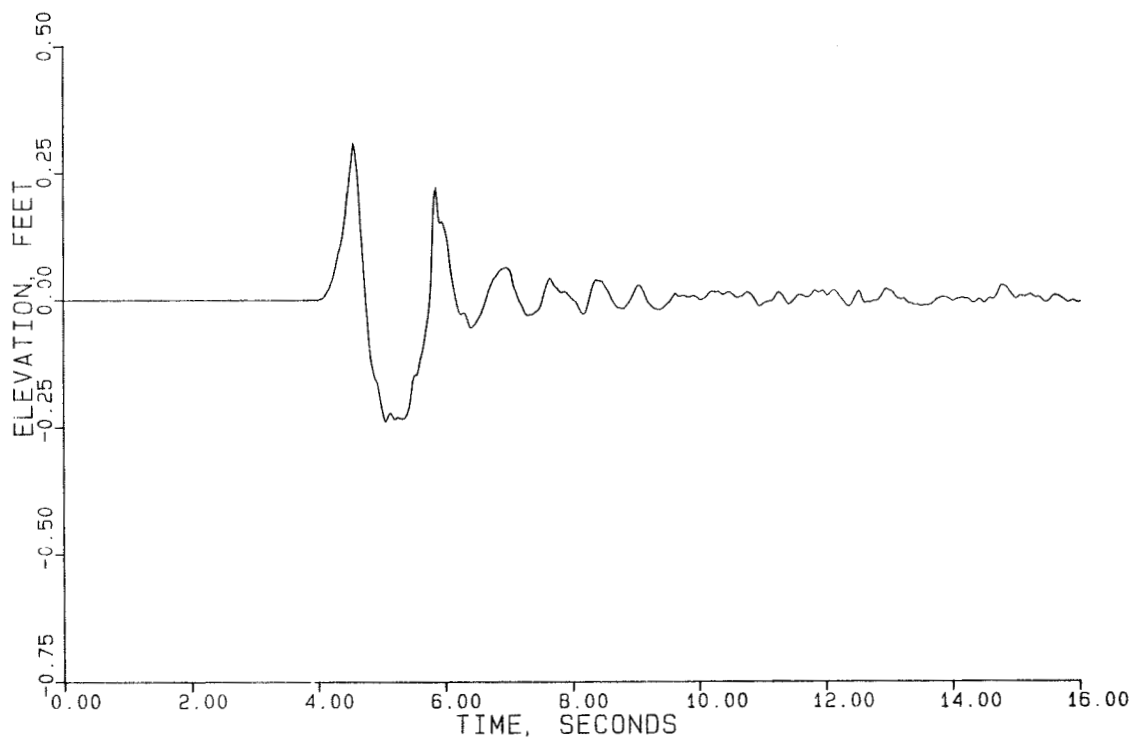
WAVE TRAIN TIME HISTORY  
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TEST 6 , GAGE 1



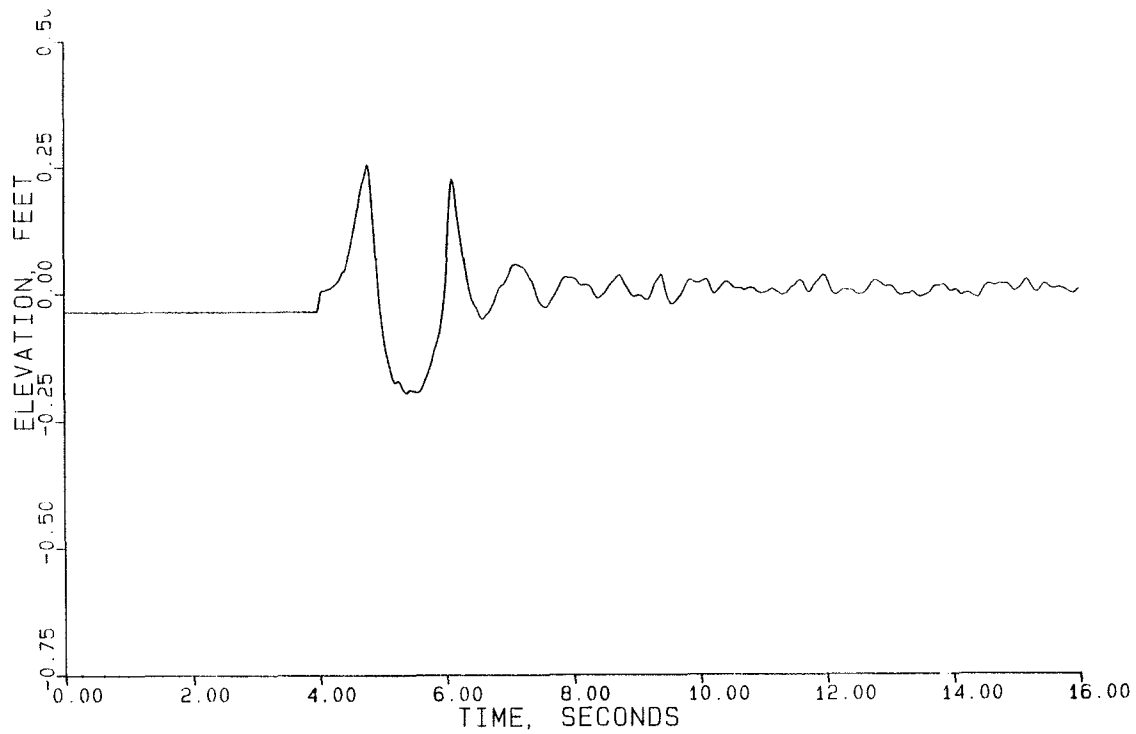
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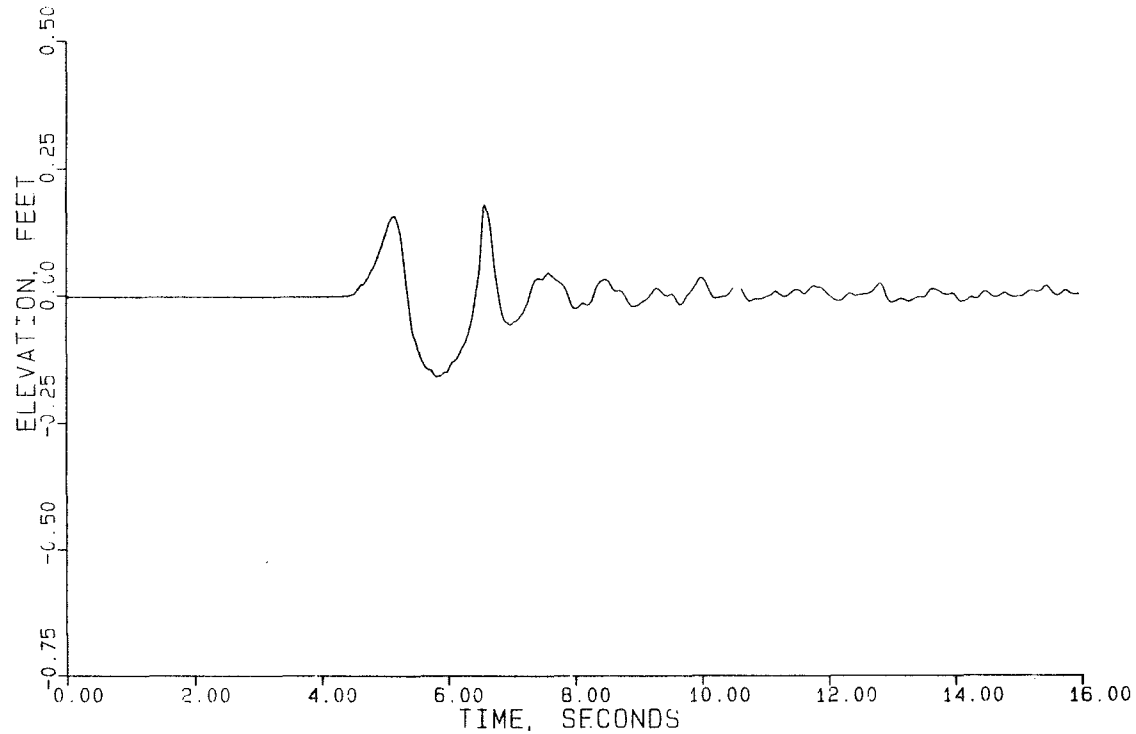
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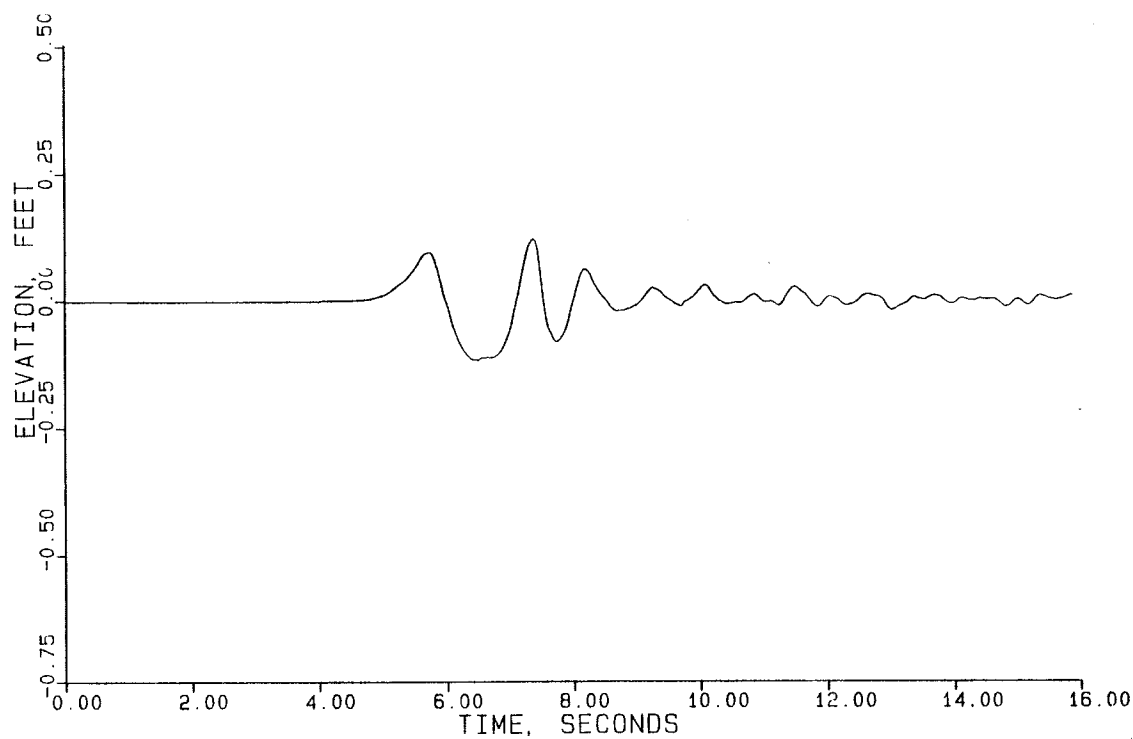
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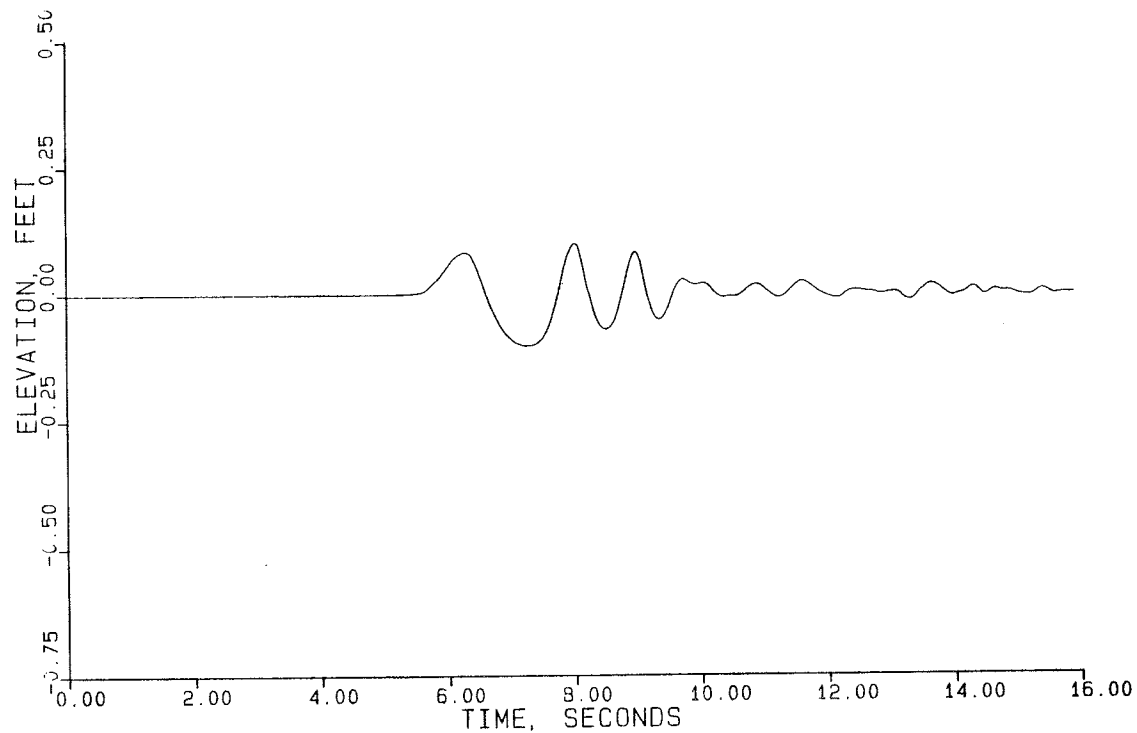
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WAVE TRAIN TIME HISTORY  
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TEST 6 , GAGE 6

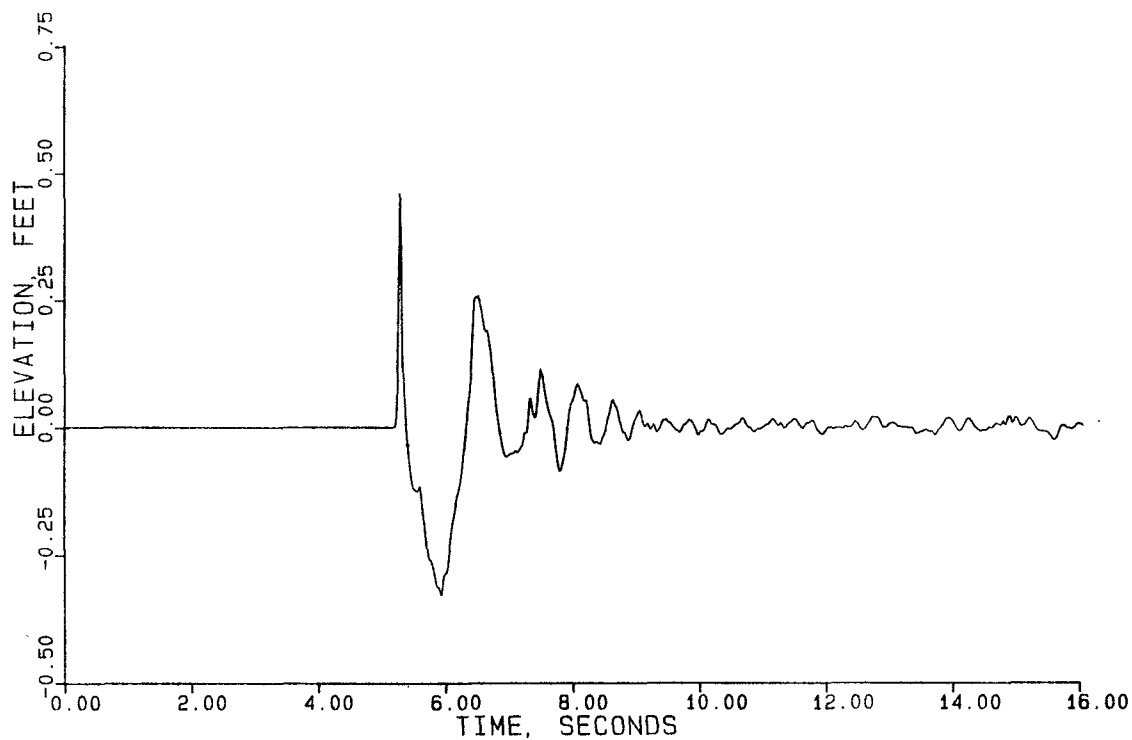


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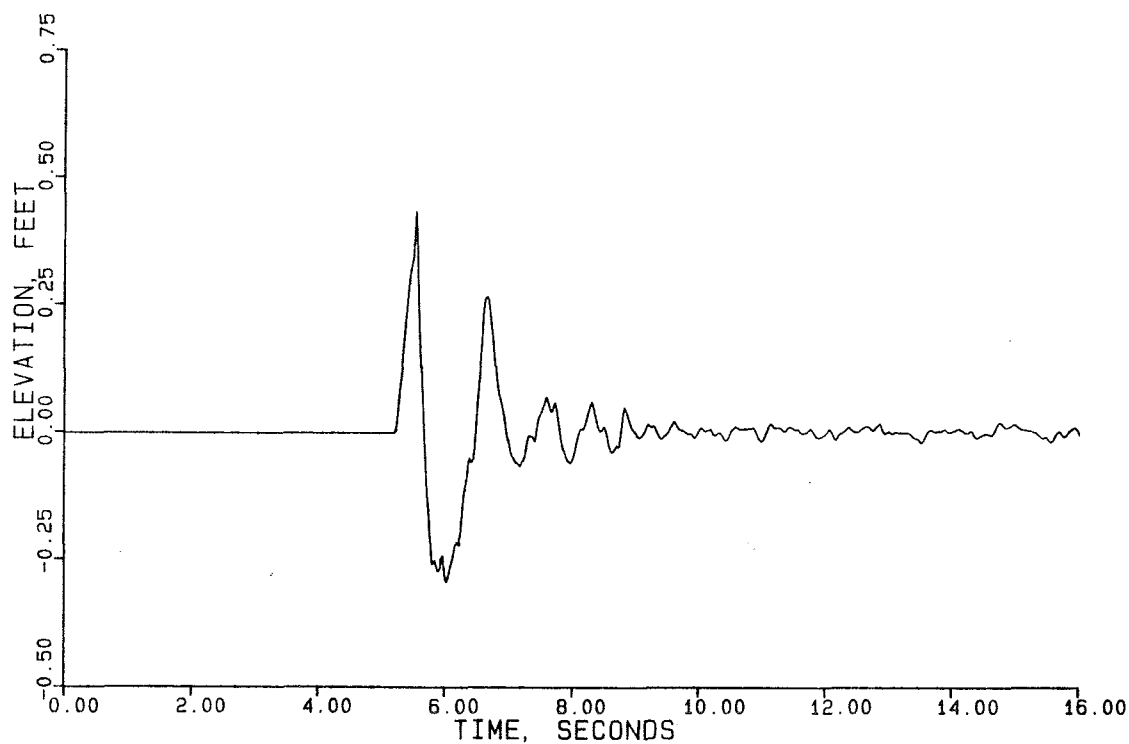


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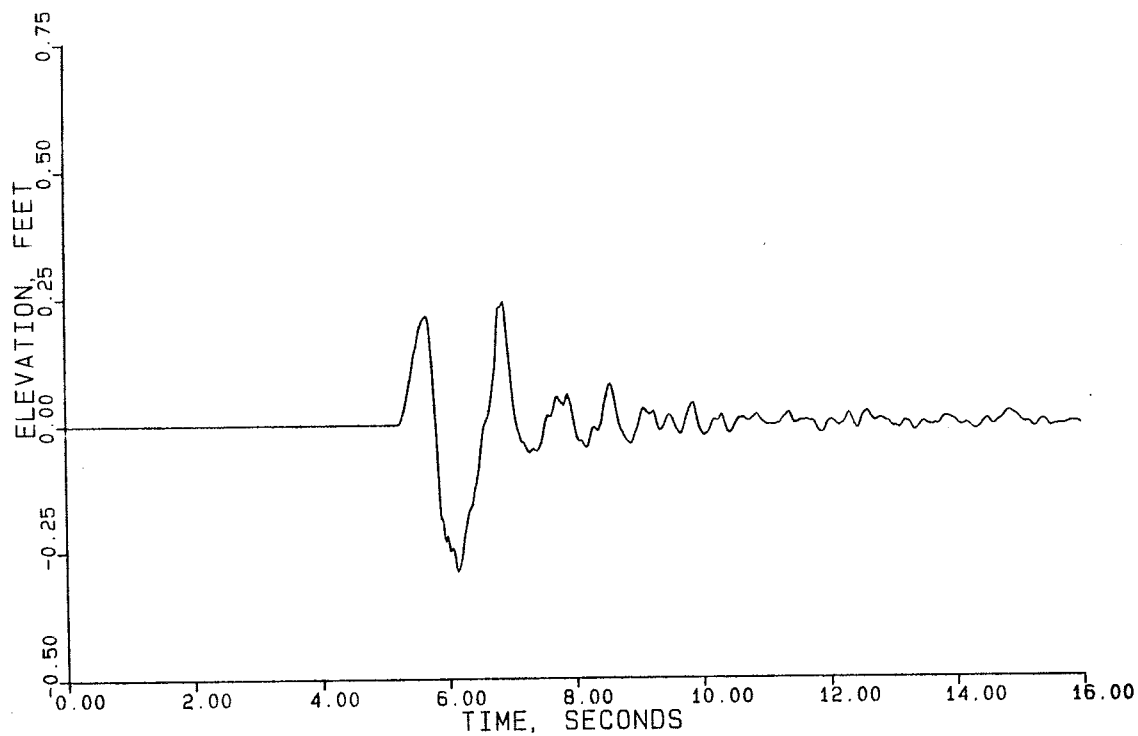




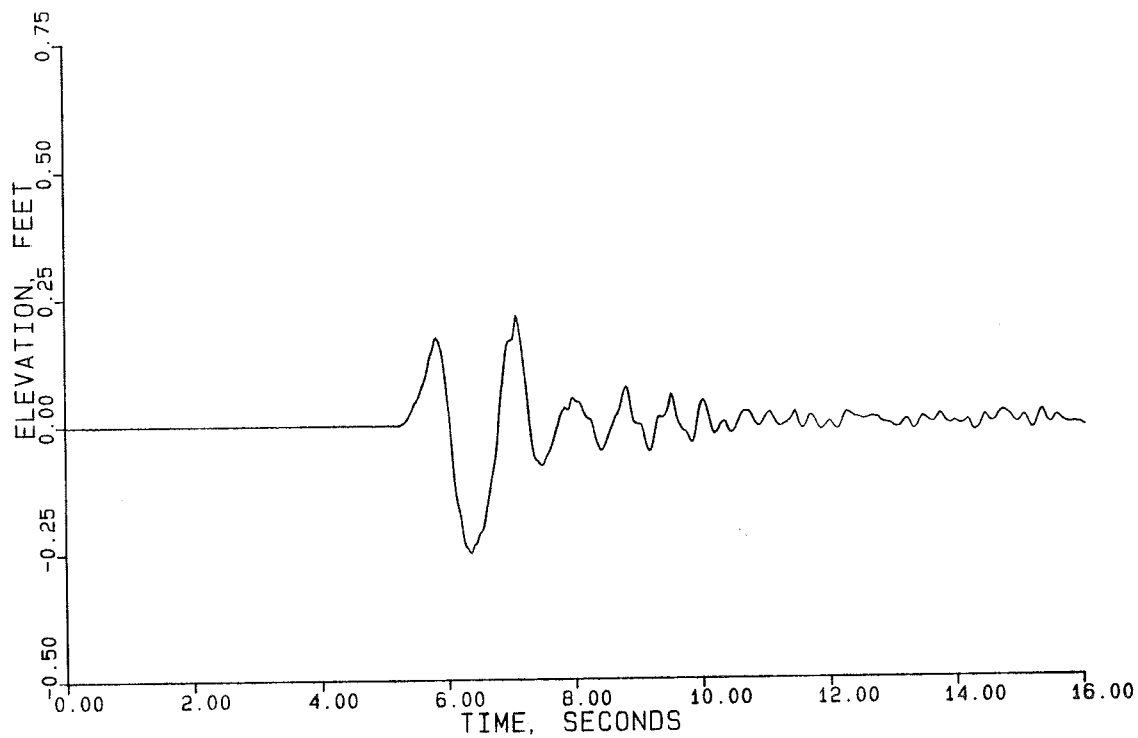
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TEST 7 , GAGE 1



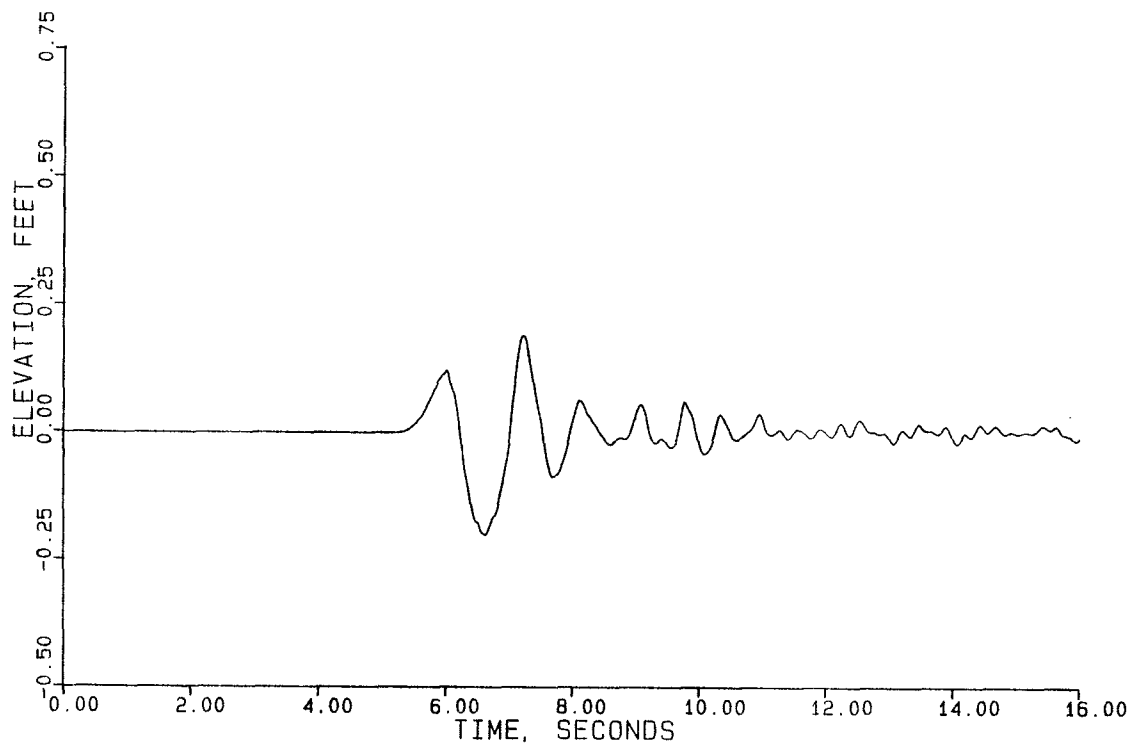
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TEST 7 , GAGE 2



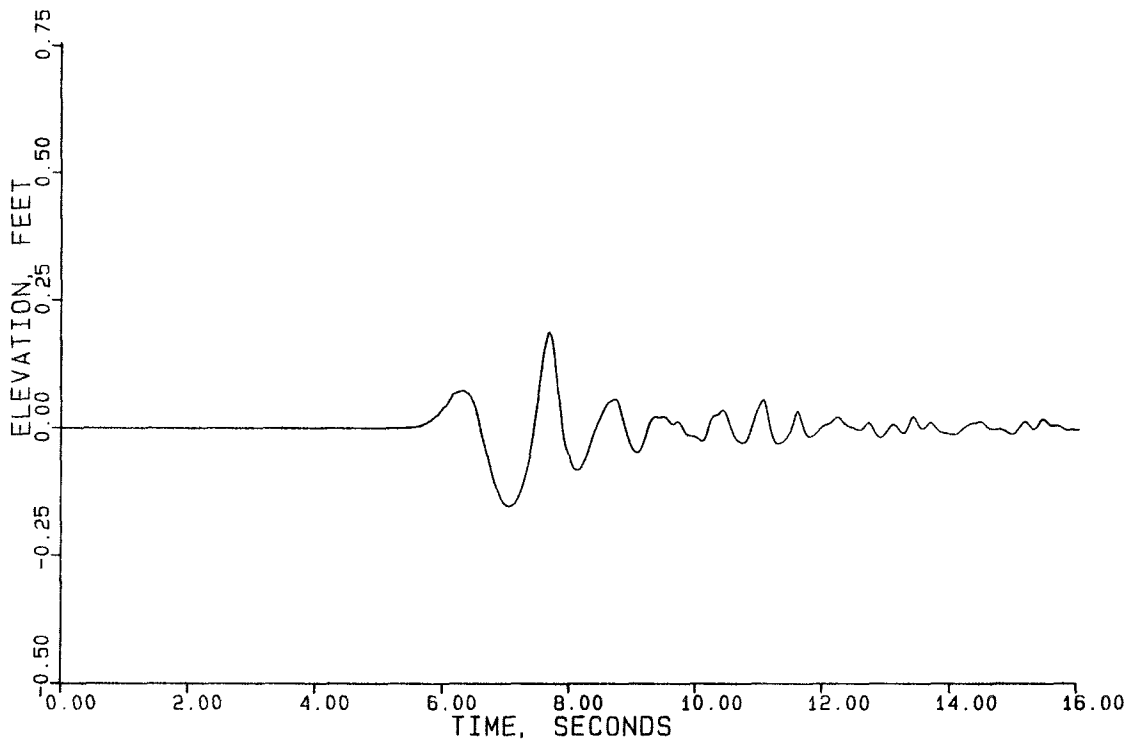
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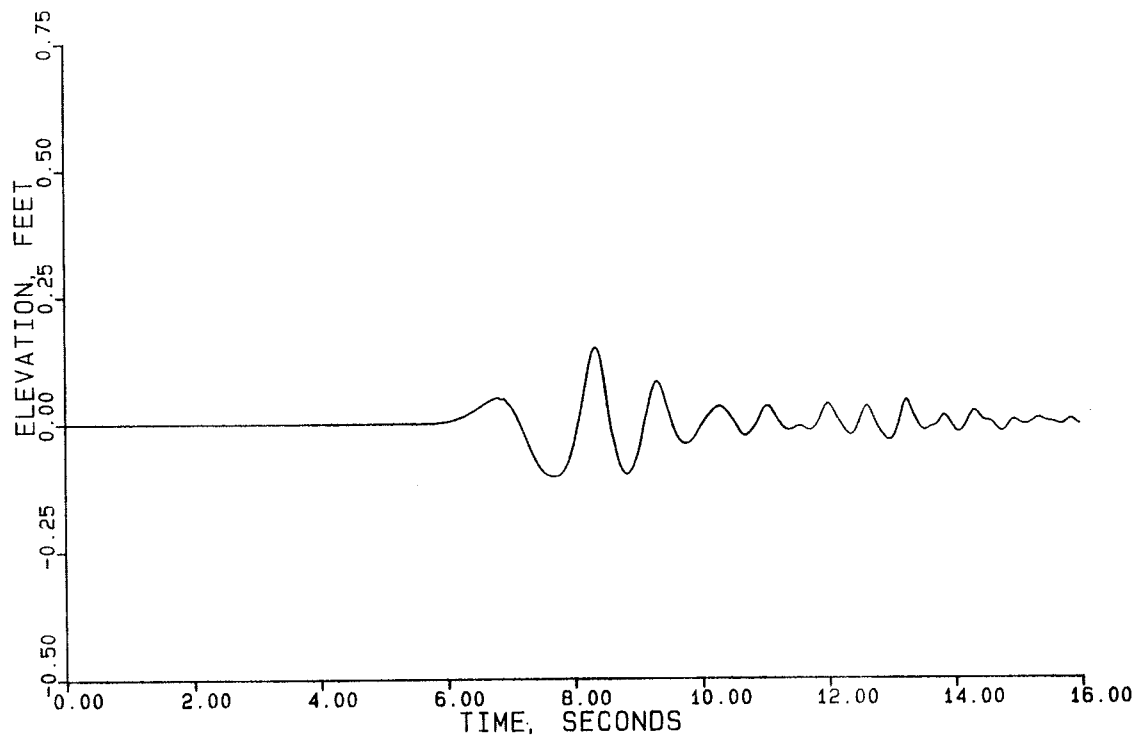
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TEST 7 , GAGE 4



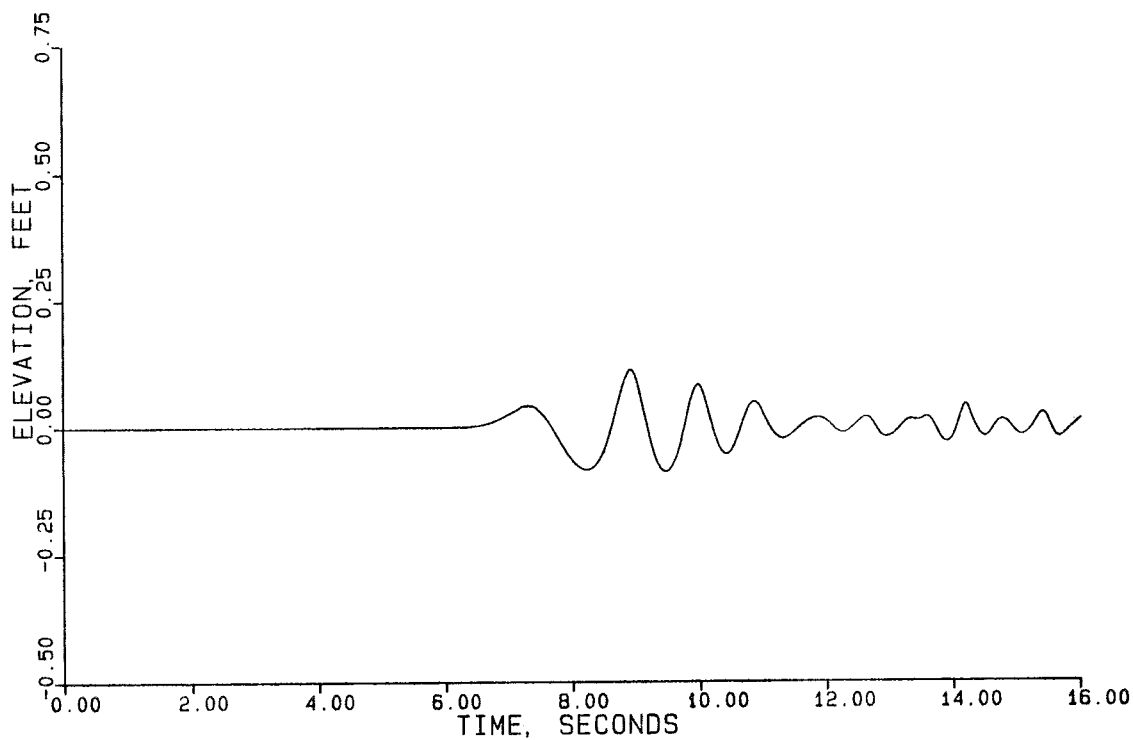
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TEST 7 , GAGE 5



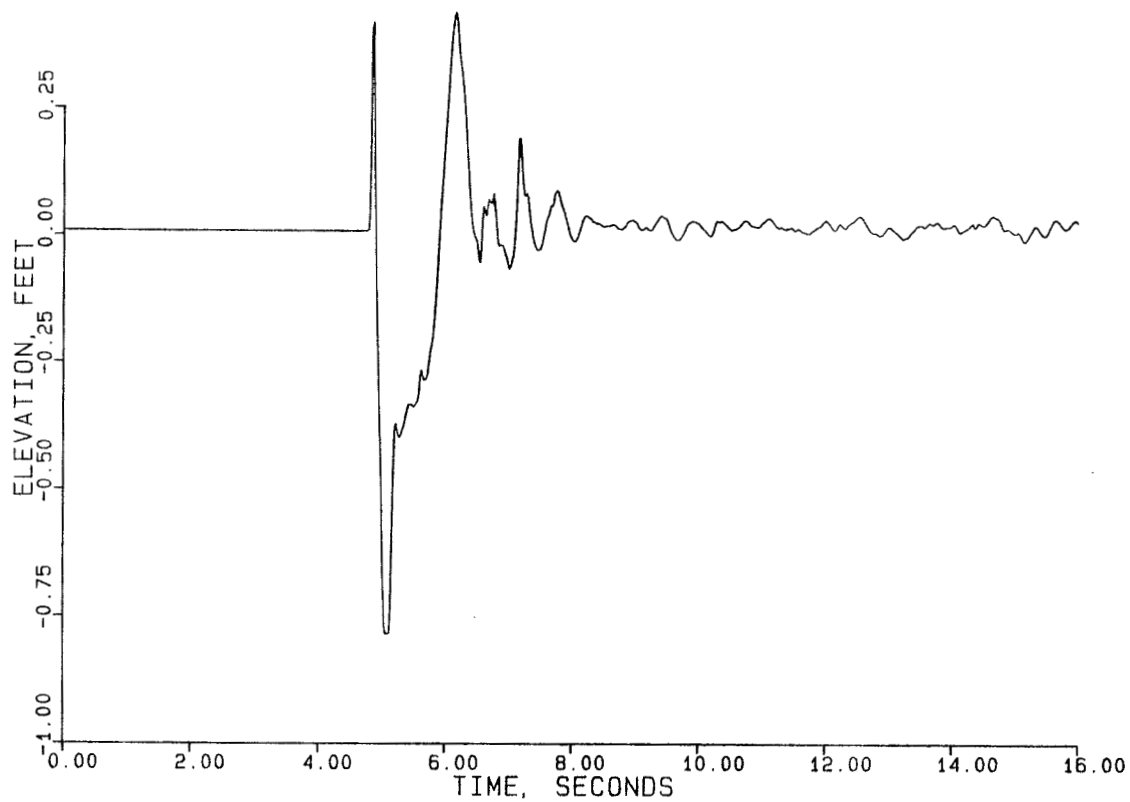
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TEST 7 , GAGE 6



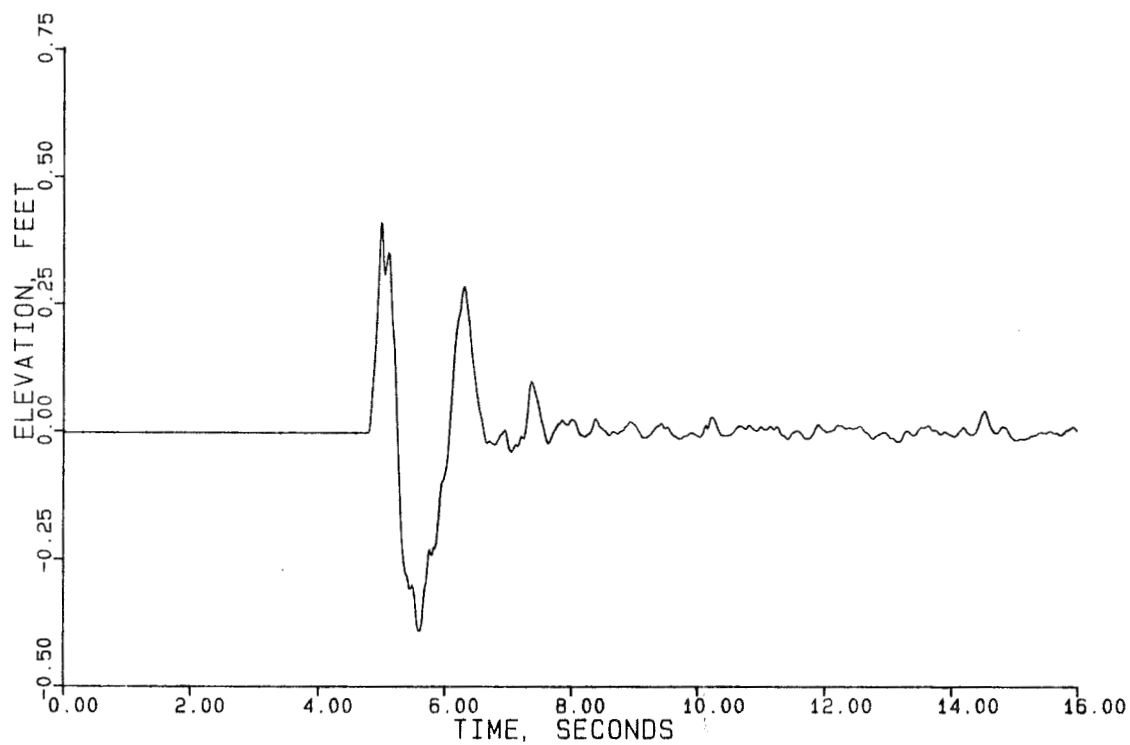
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TEST 7 , GAGE 7



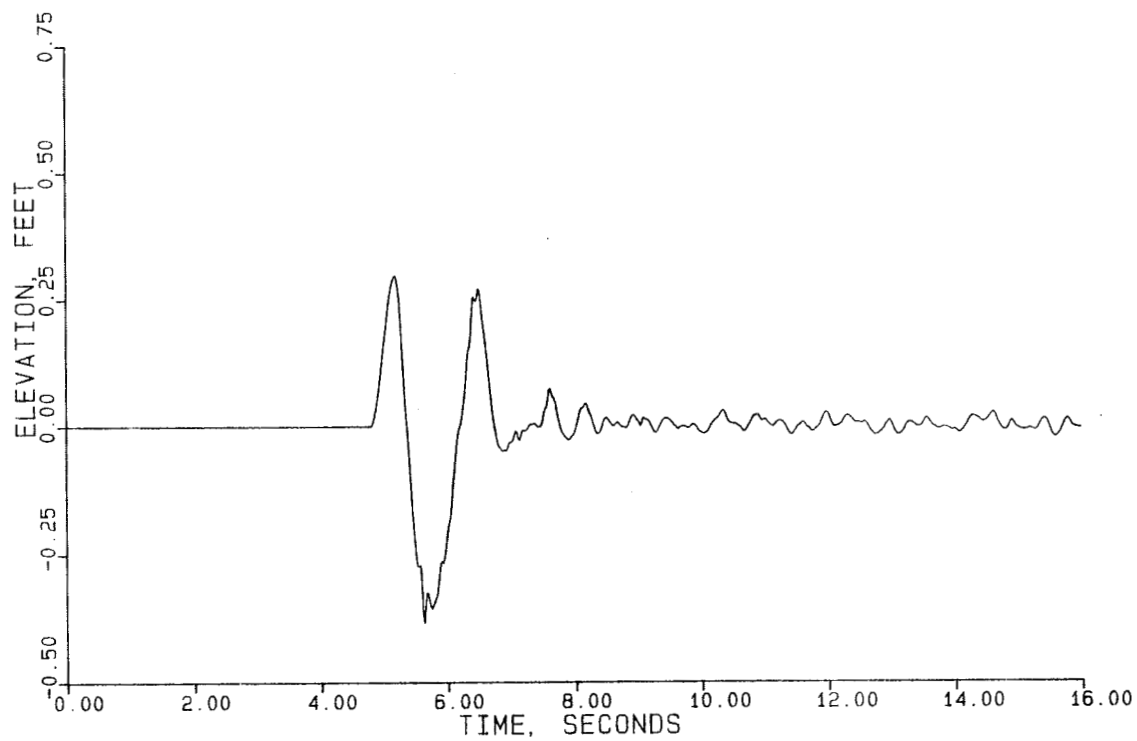
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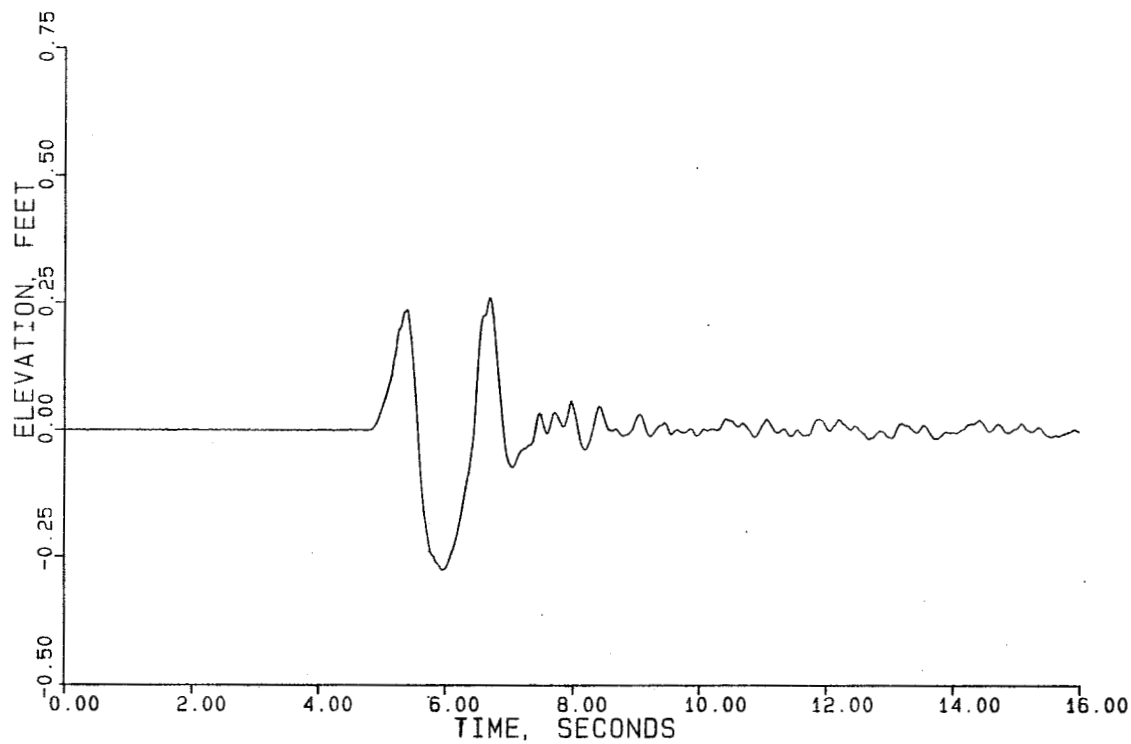
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TEST 8 , GAGE 1



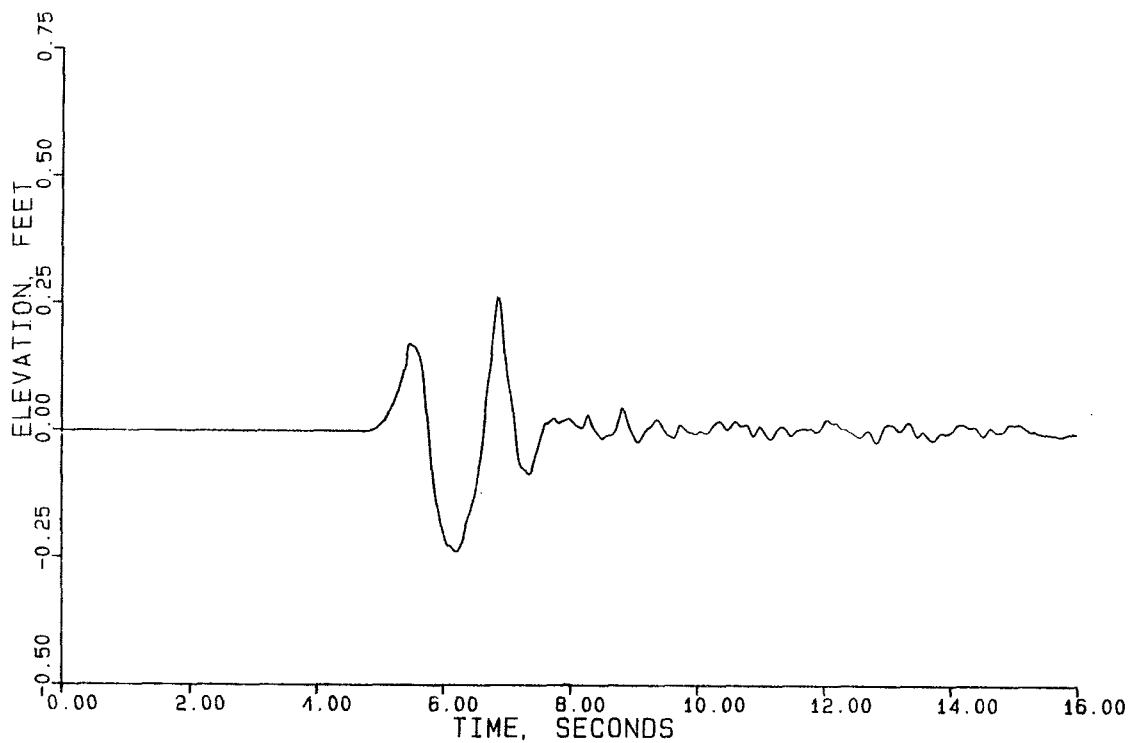
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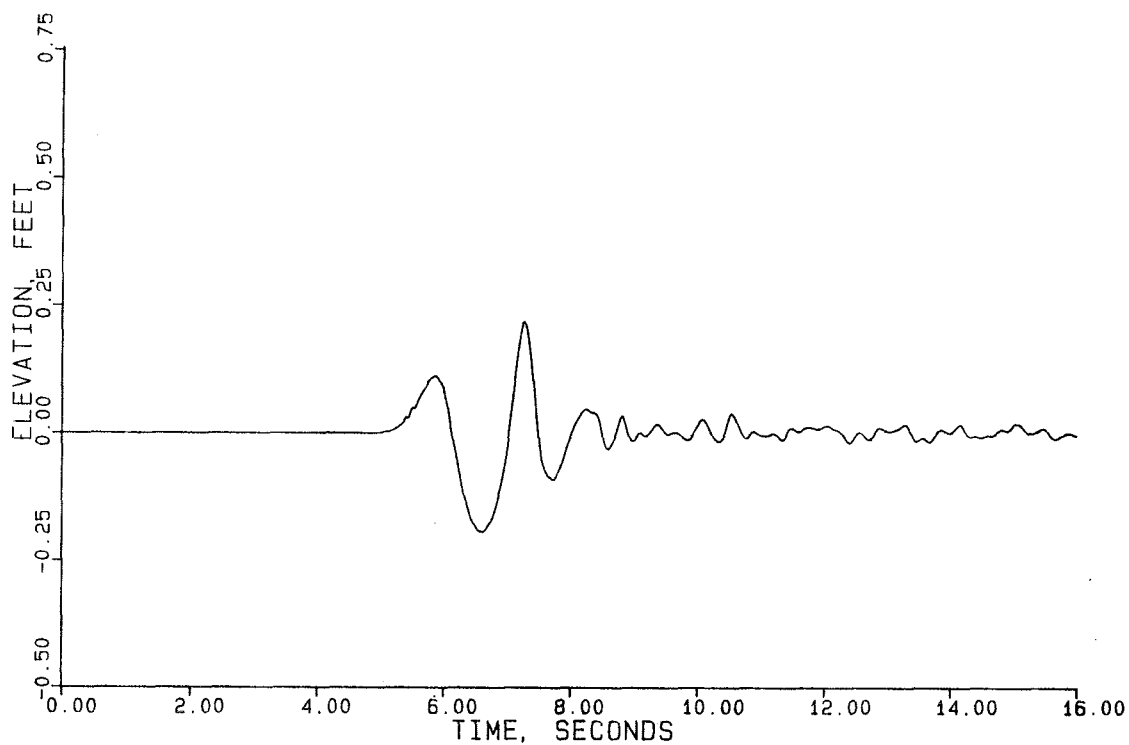
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IMPULSIVE GENERATED WAVES  
TEST 8 , GAGE 3



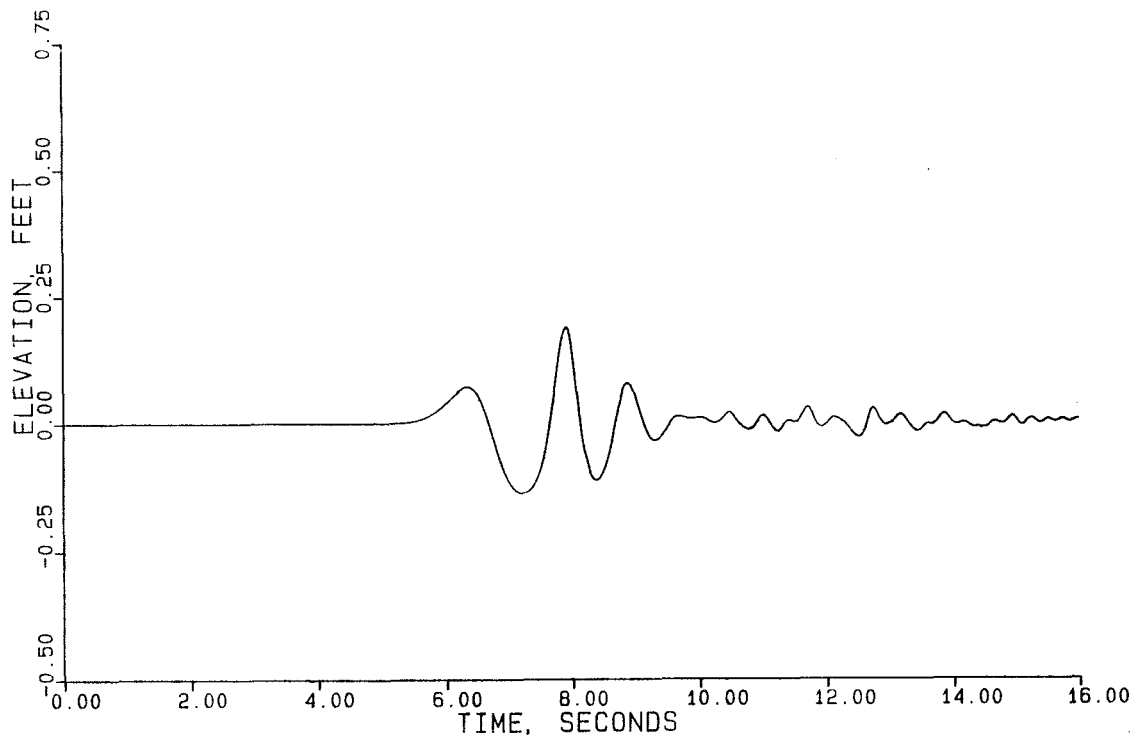
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 8 , GAGE 4



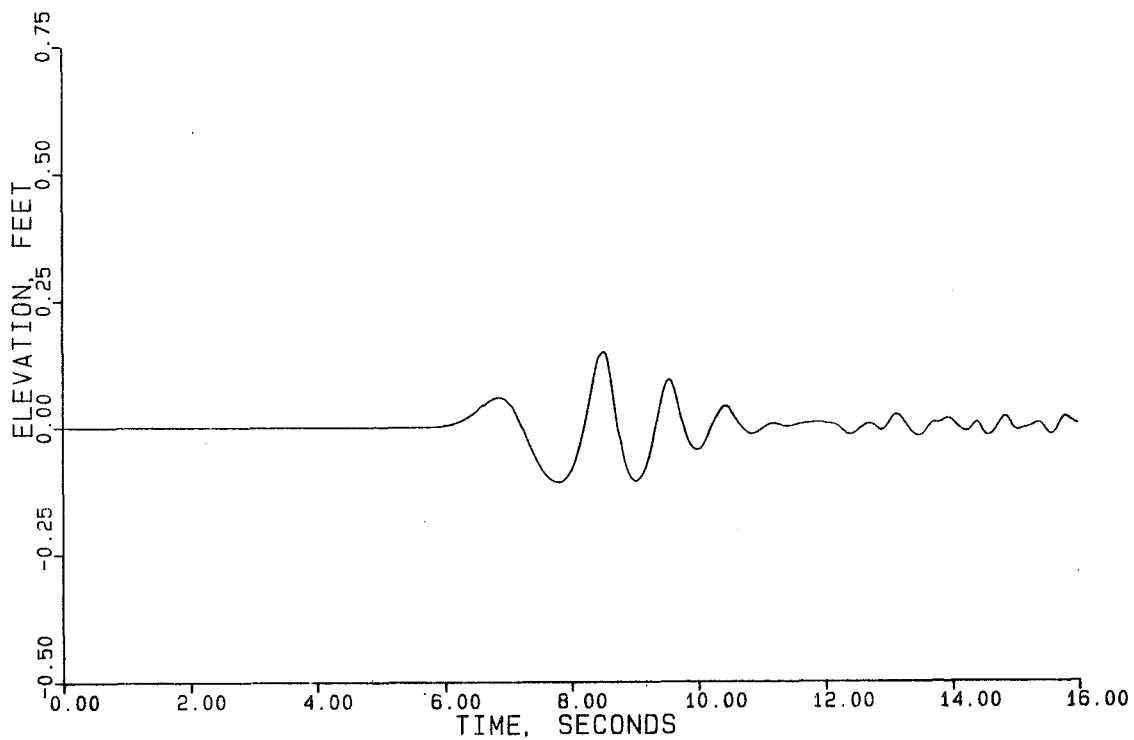
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 8 , GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 8 , GAGE 6

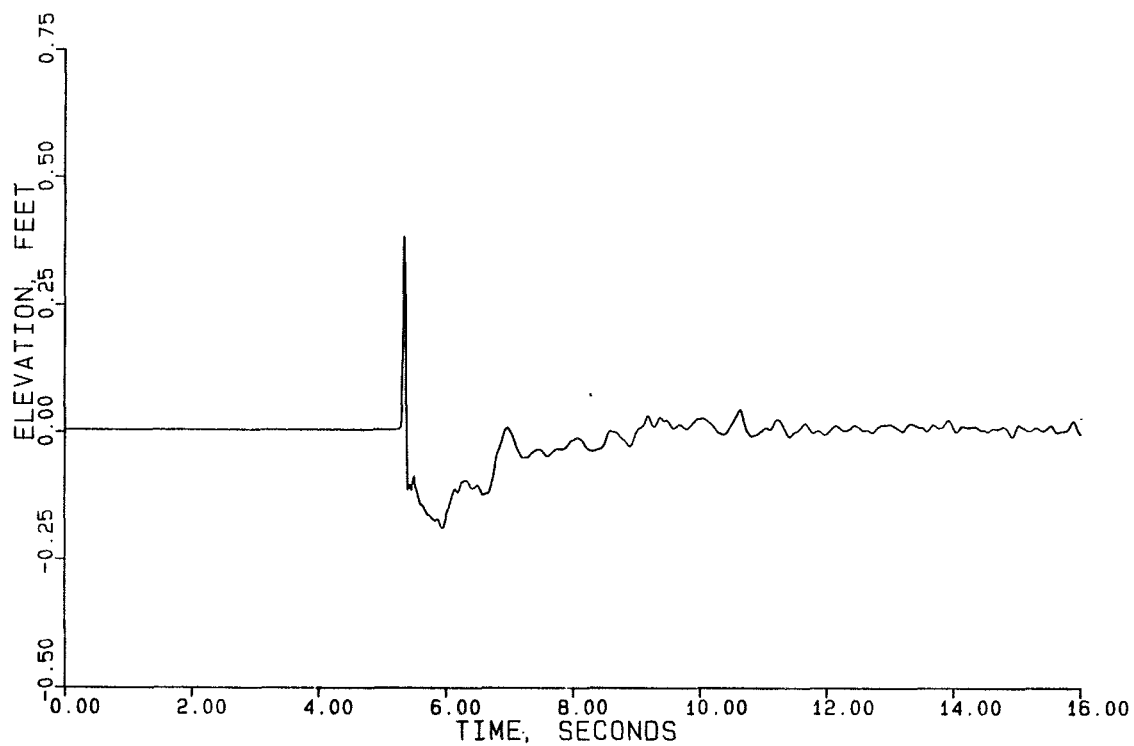


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 8 , GAGE 7

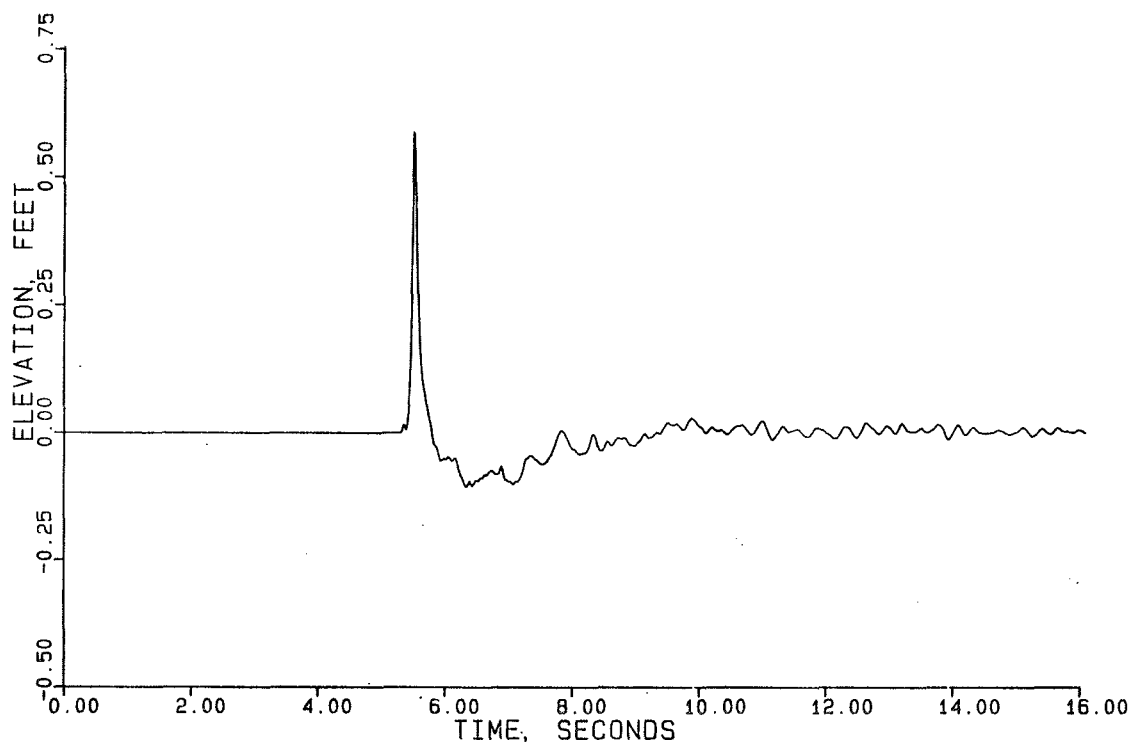


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 8 , GAGE 8

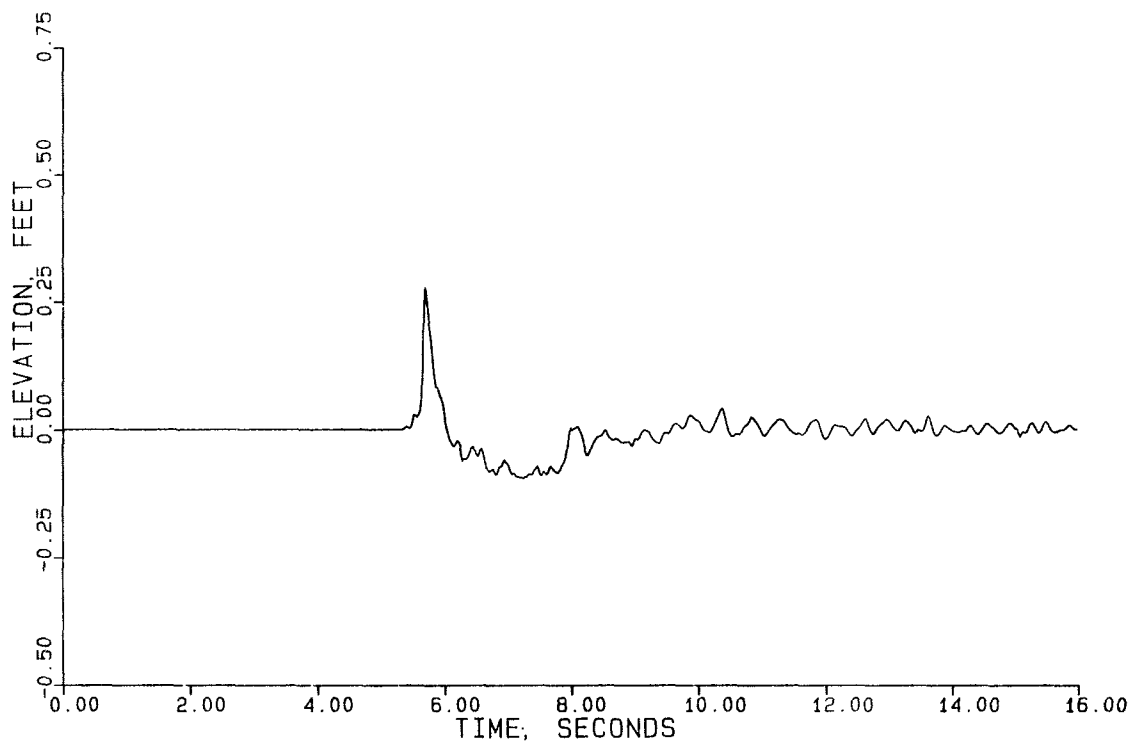




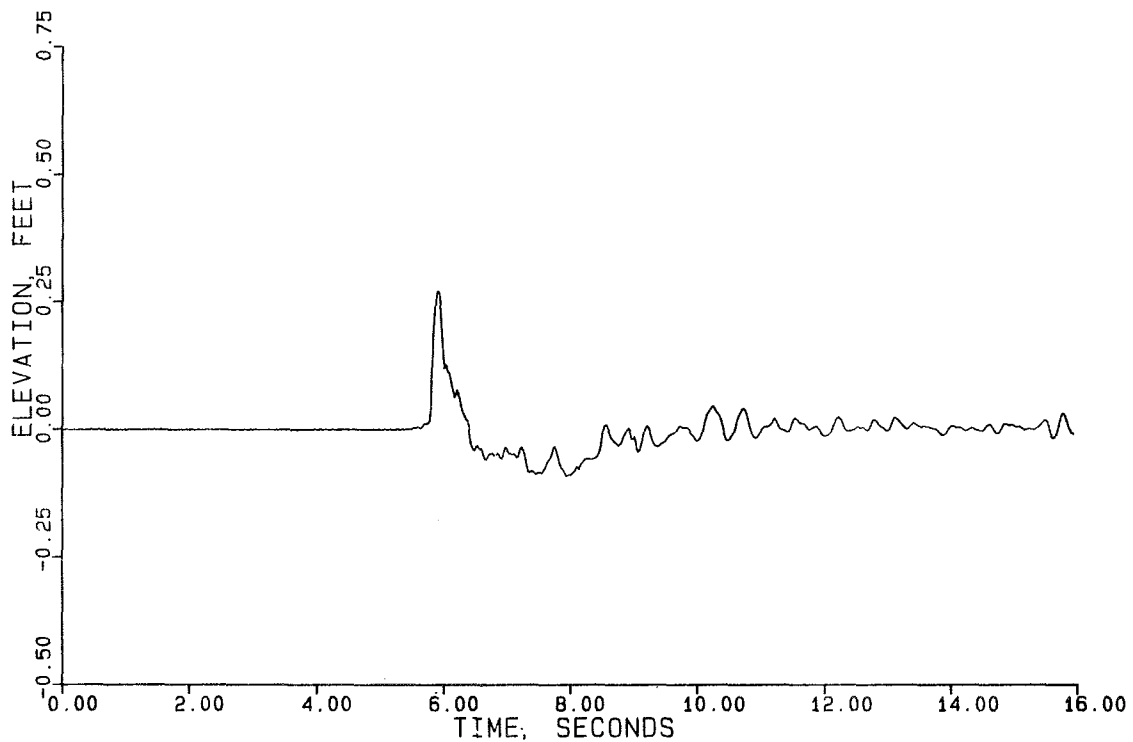
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 1



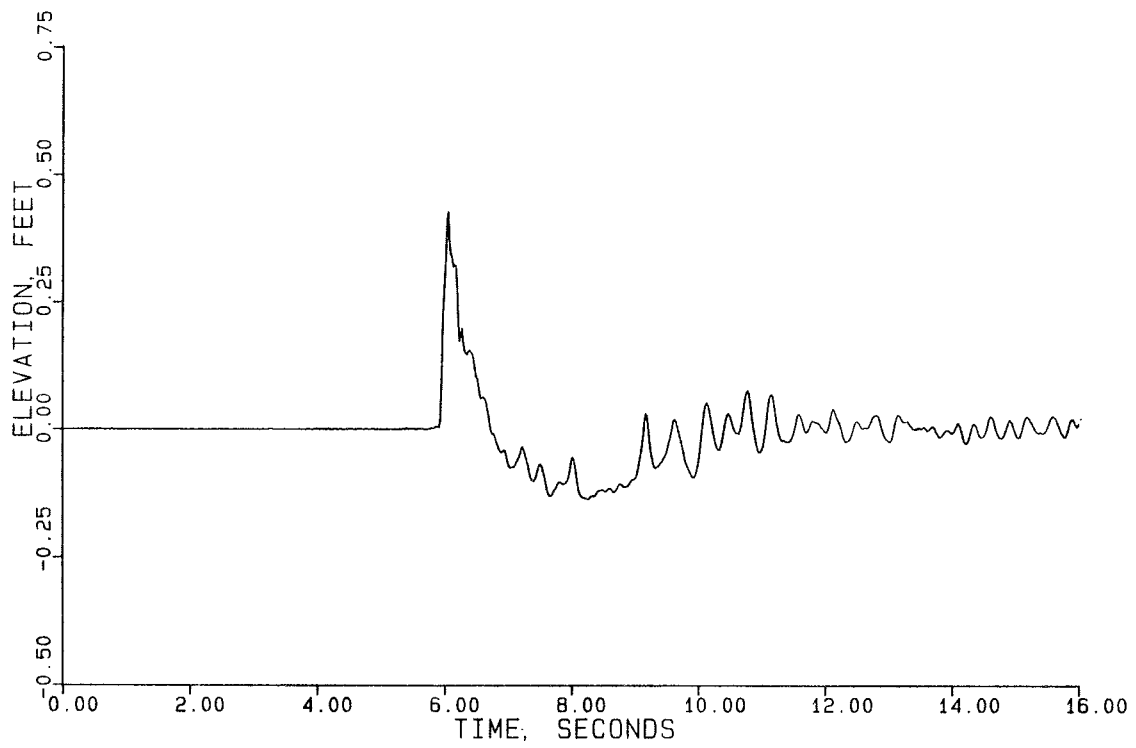
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 2



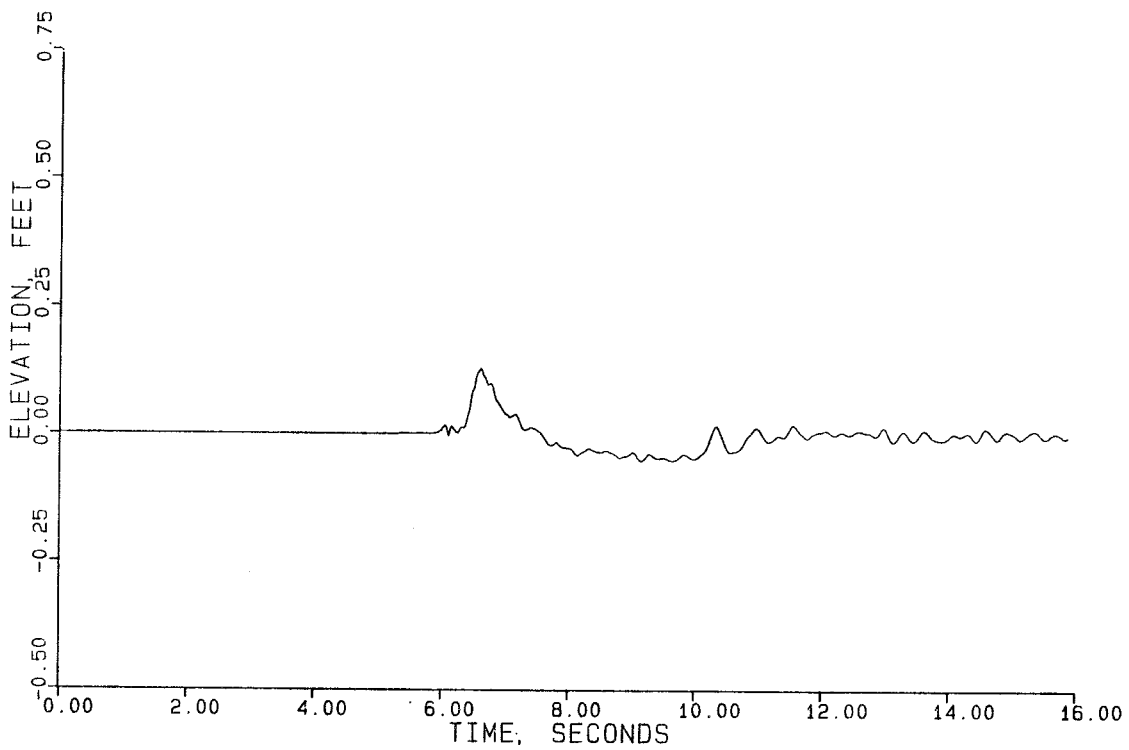
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 3



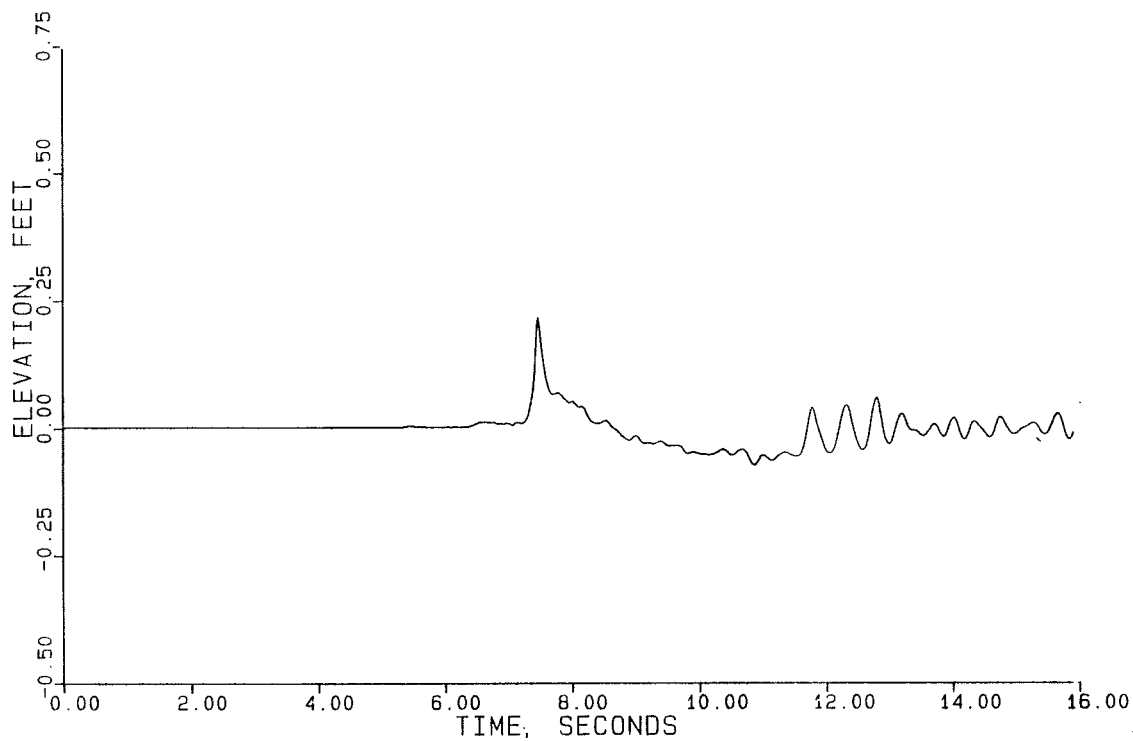
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 4



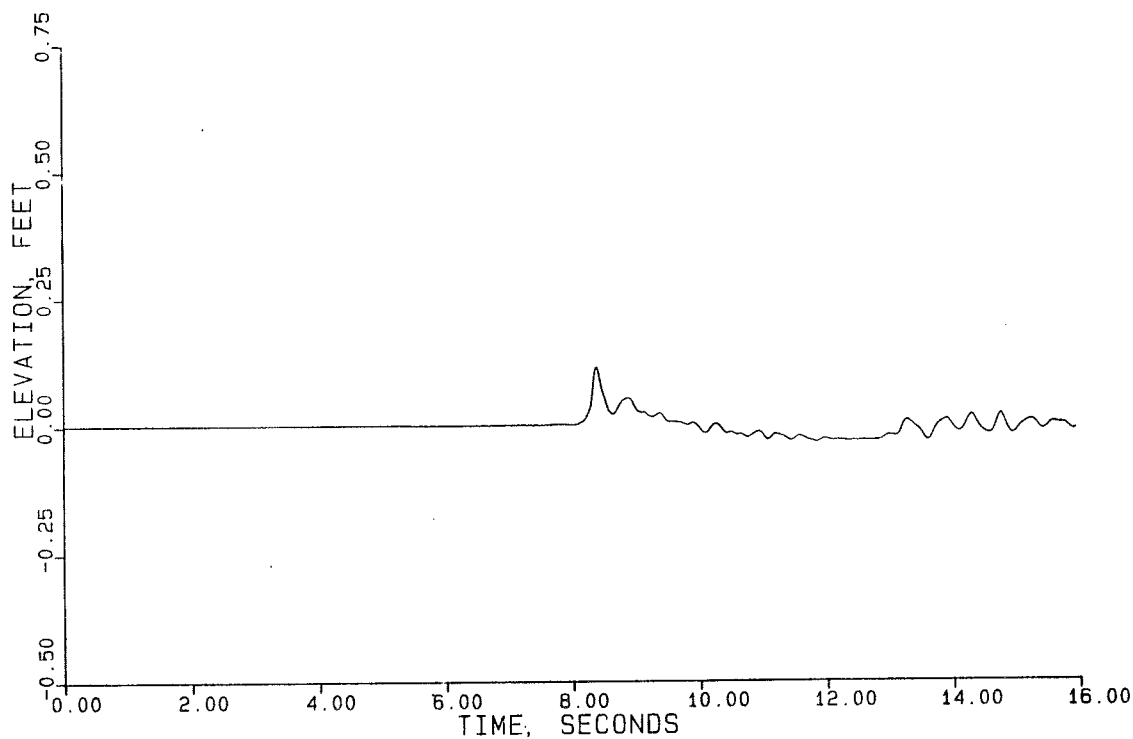
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 5



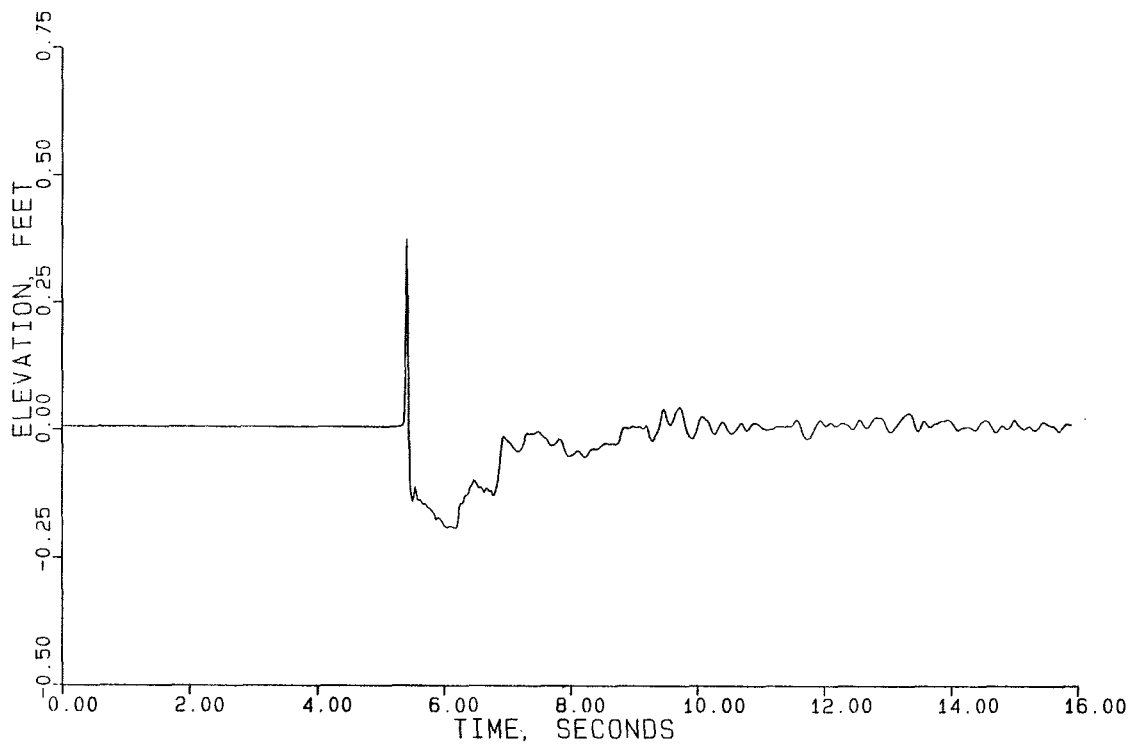
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 6



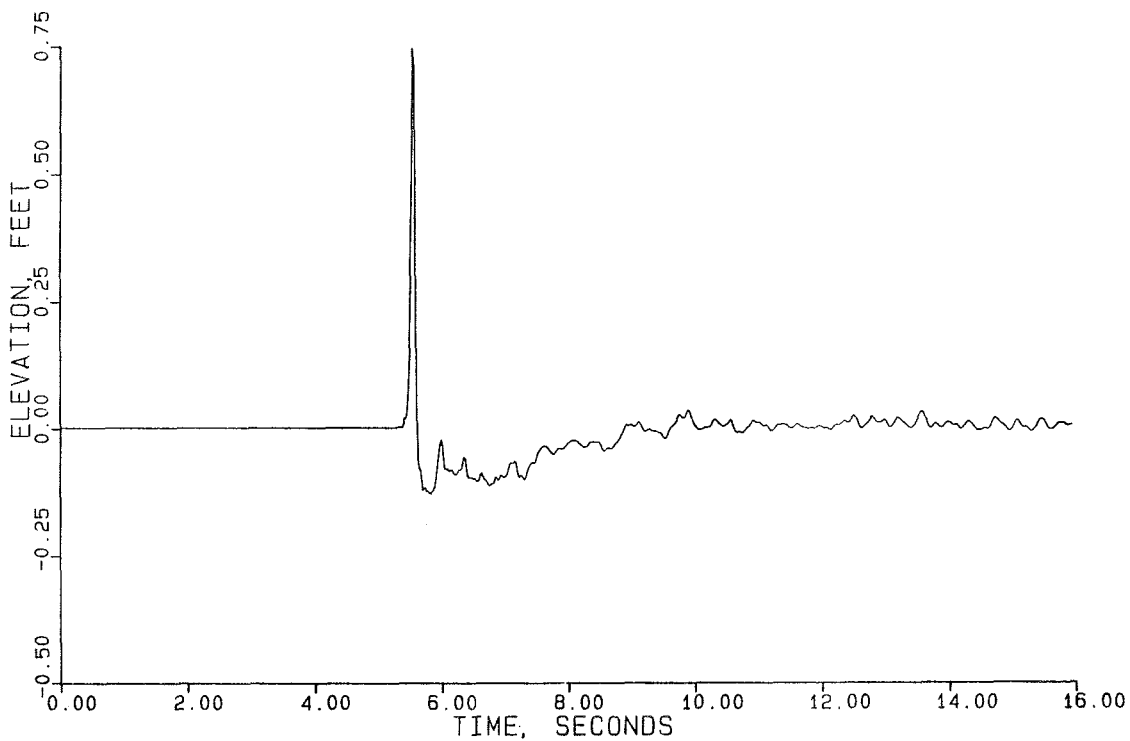
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 7



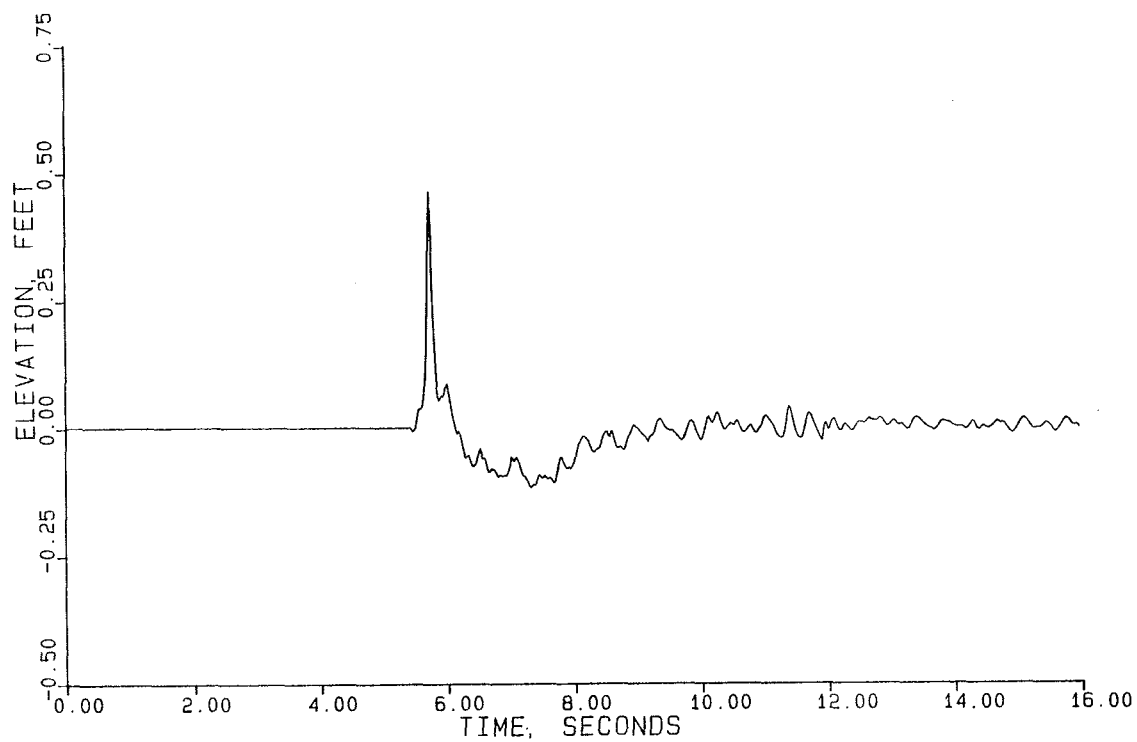
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 9 , GAGE 8



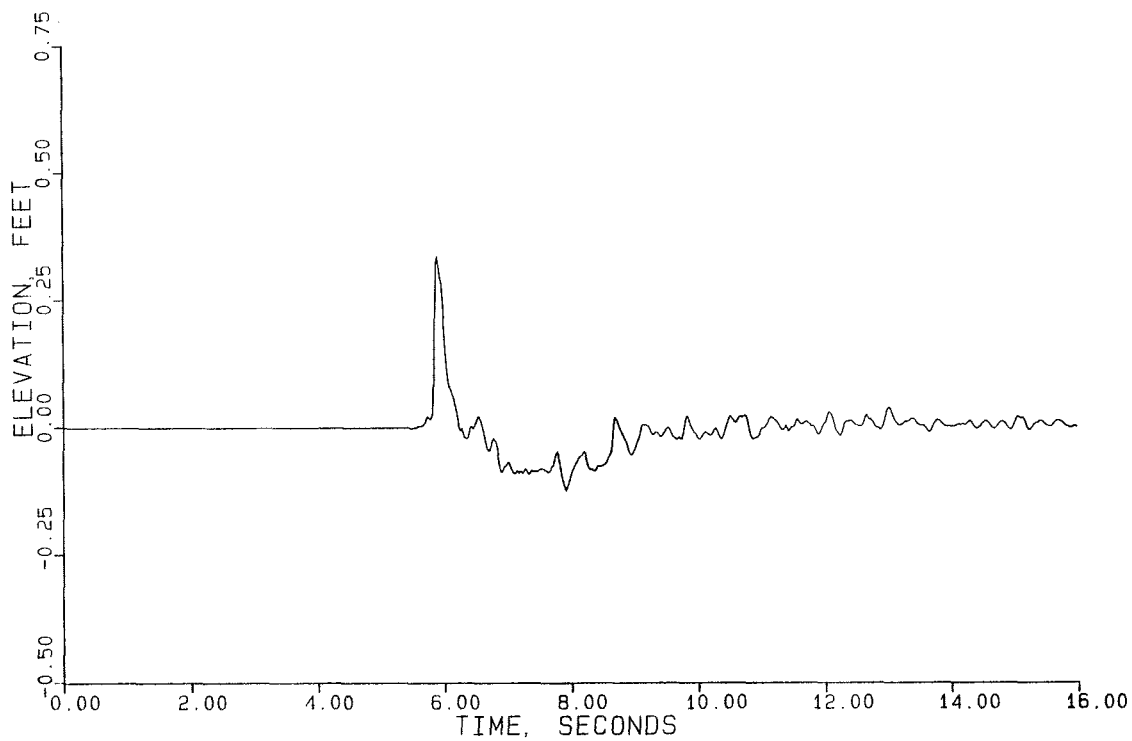
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 1



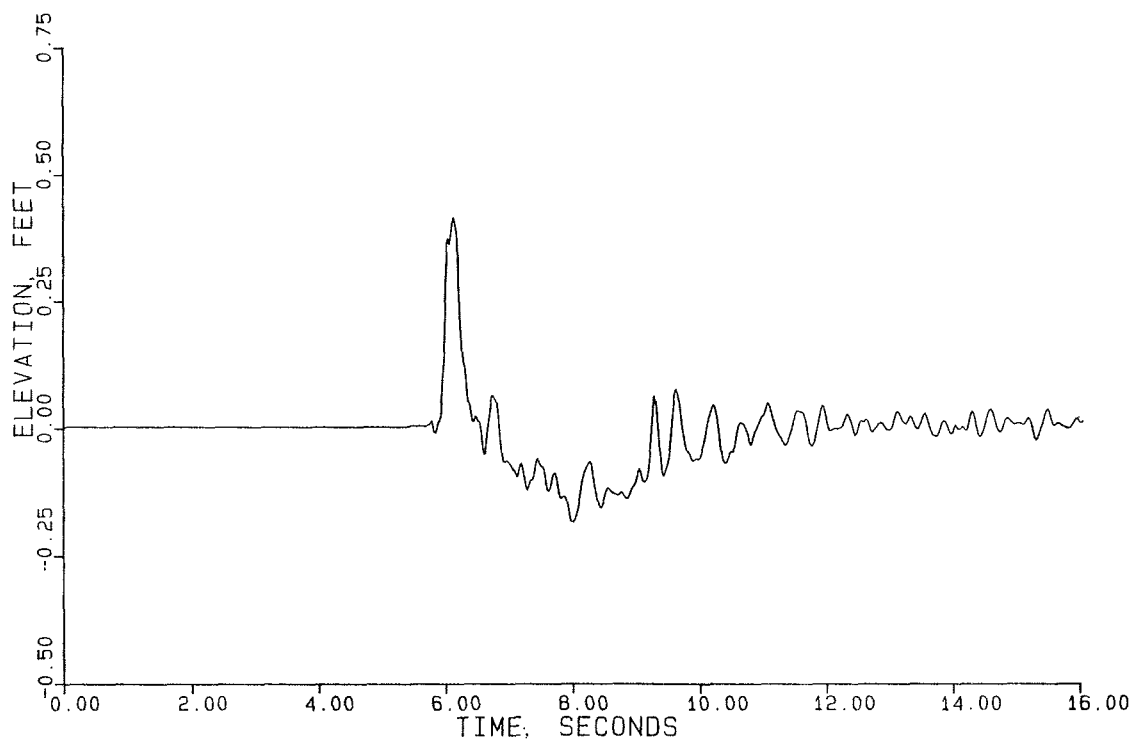
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 2



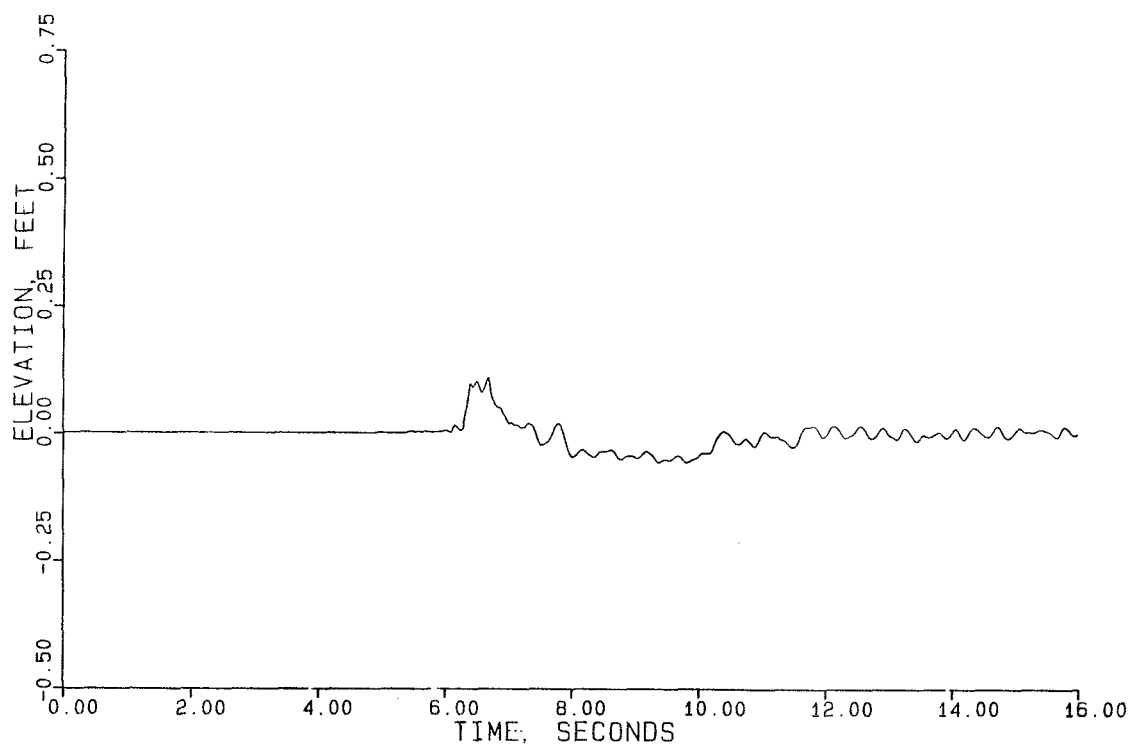
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 3



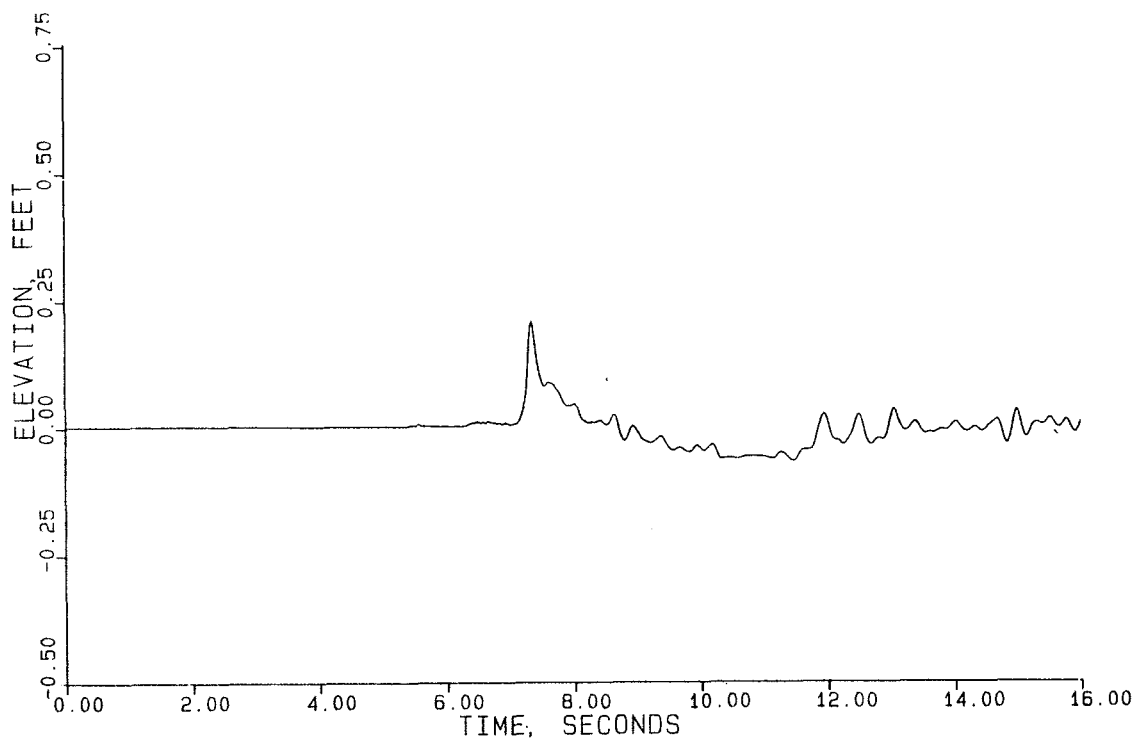
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 4



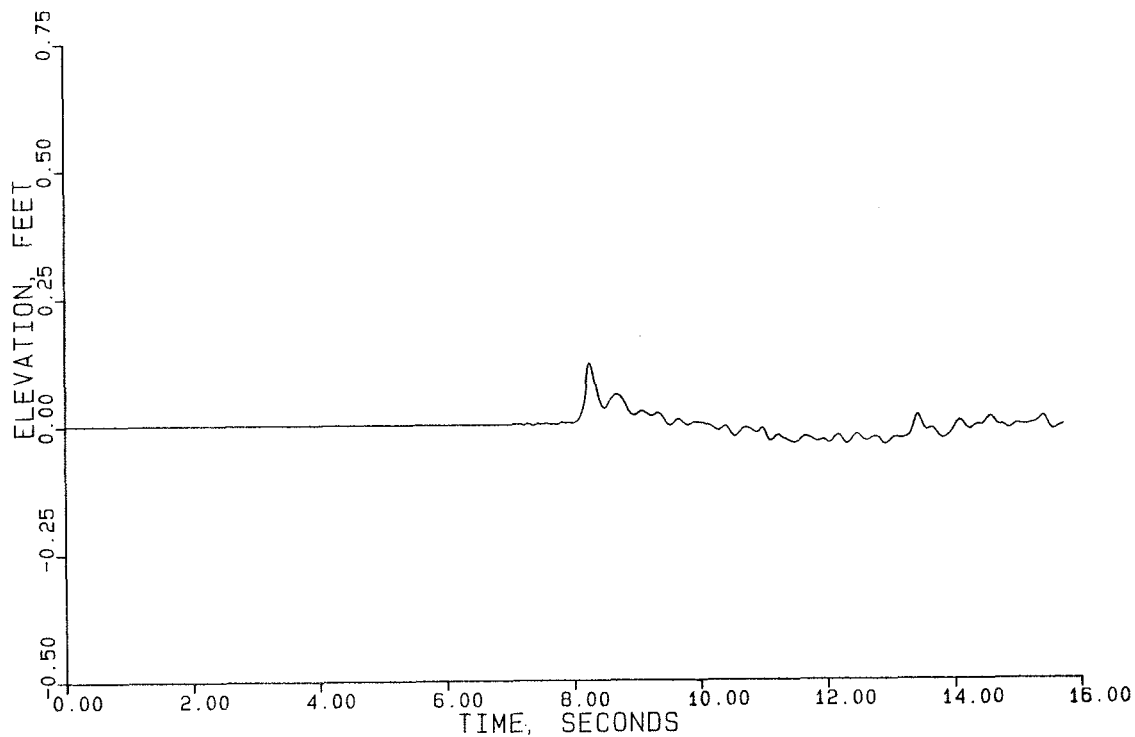
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 6

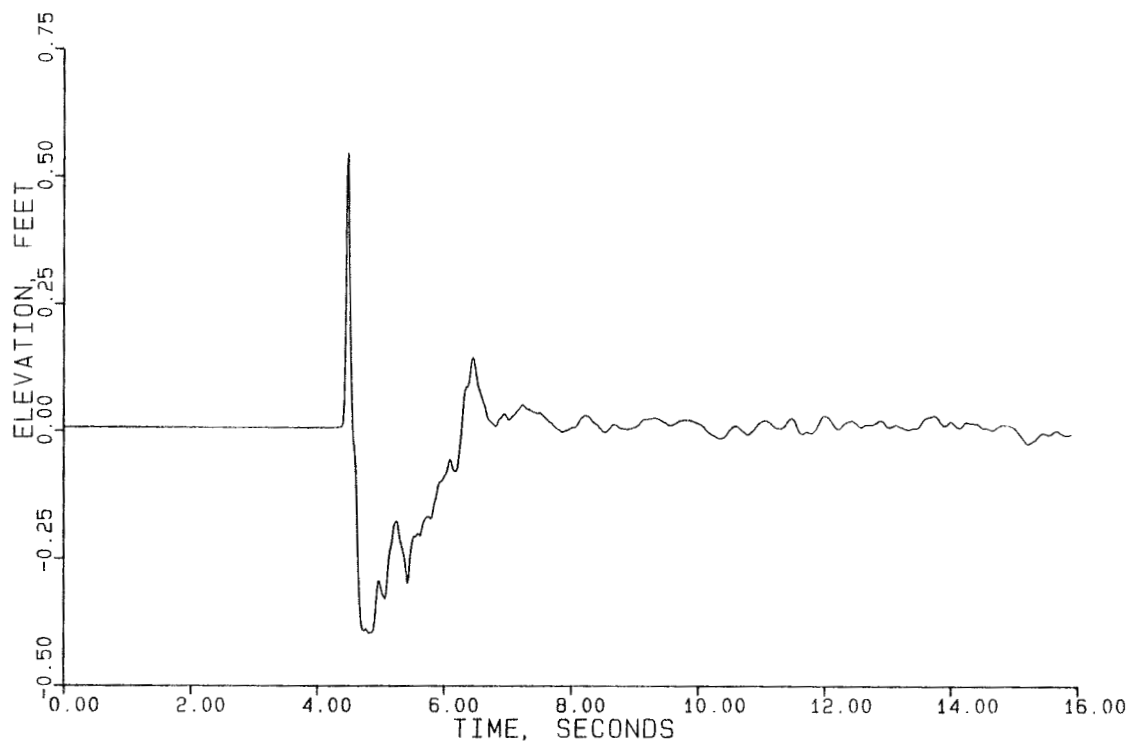


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 7

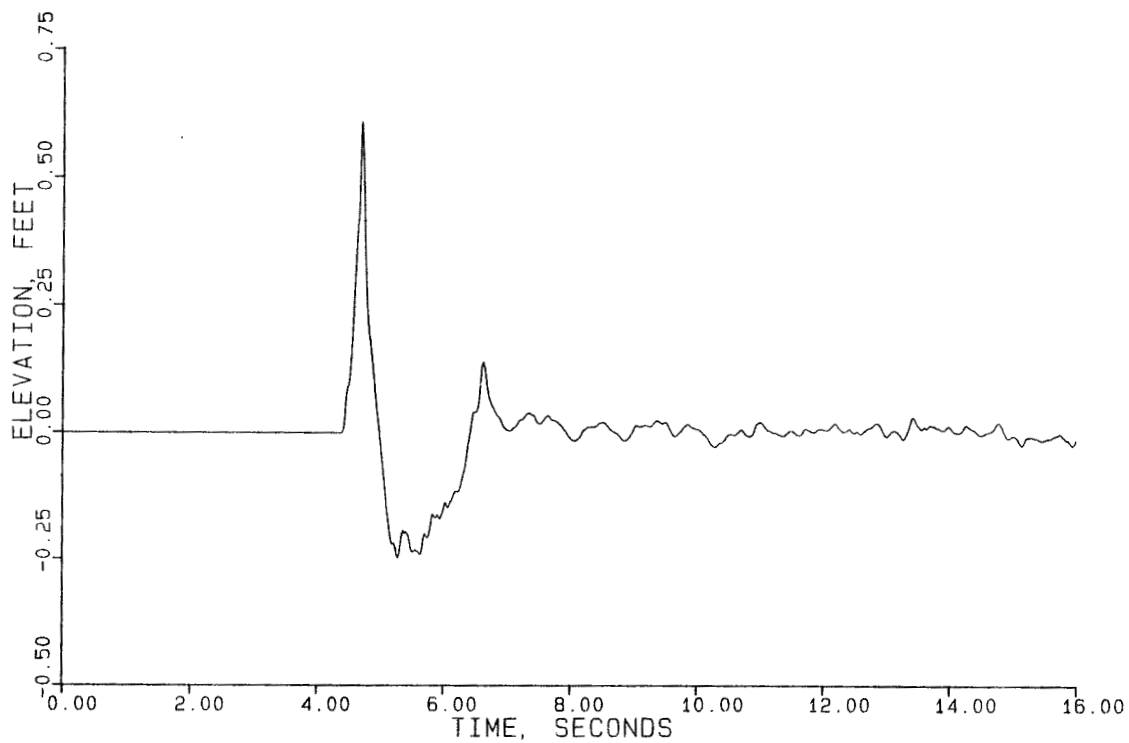


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 10, GAGE 8

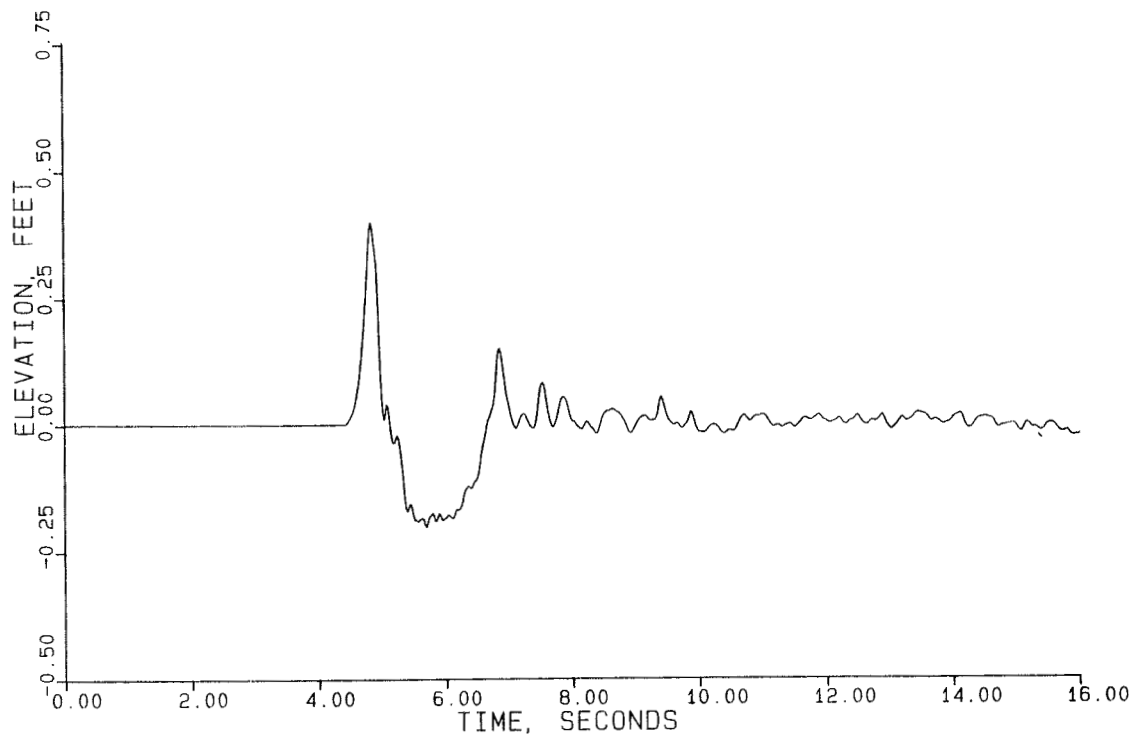




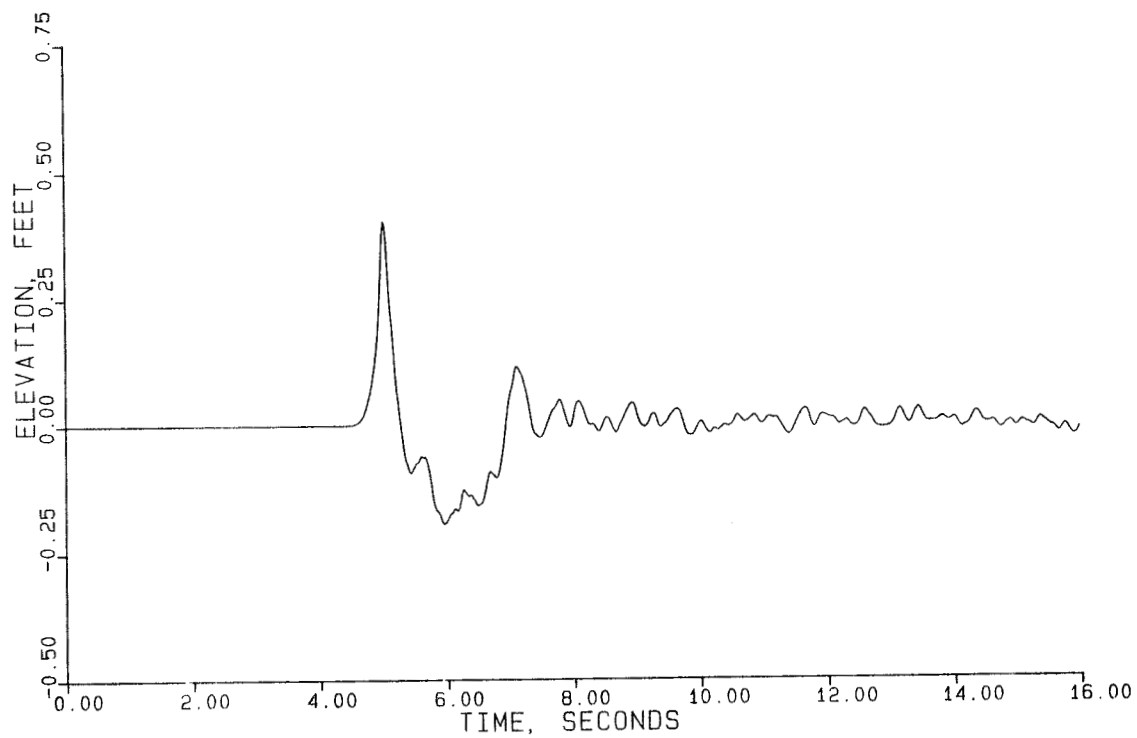
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 1



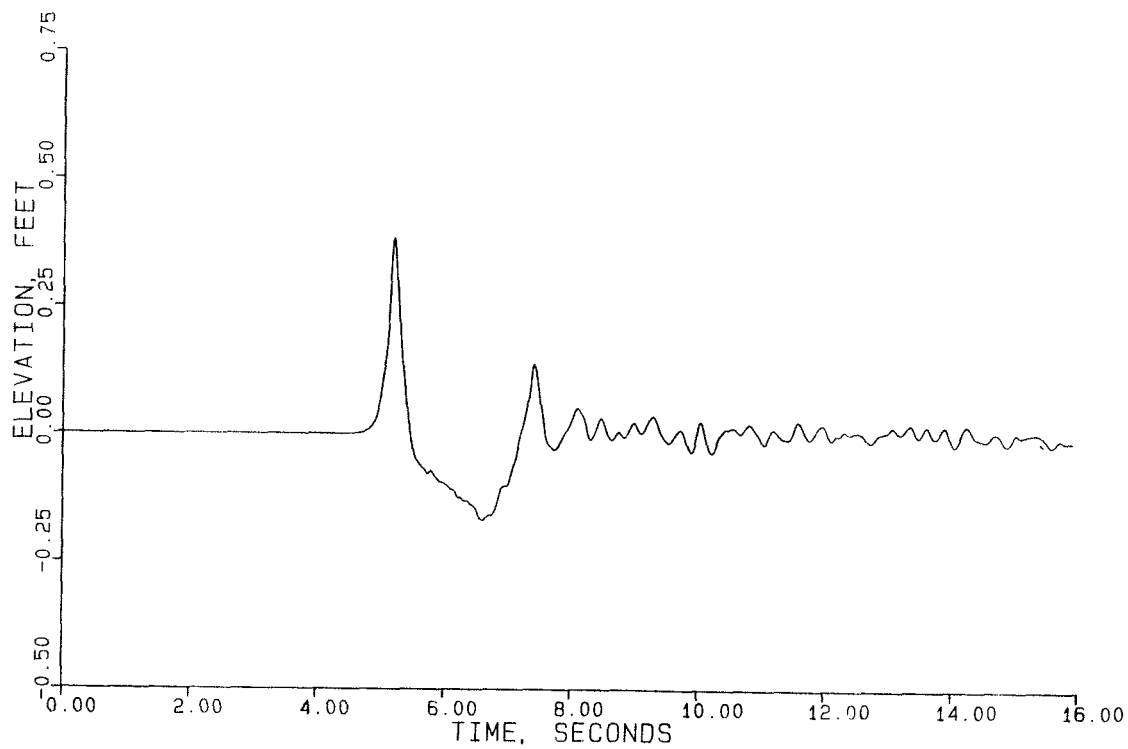
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 2



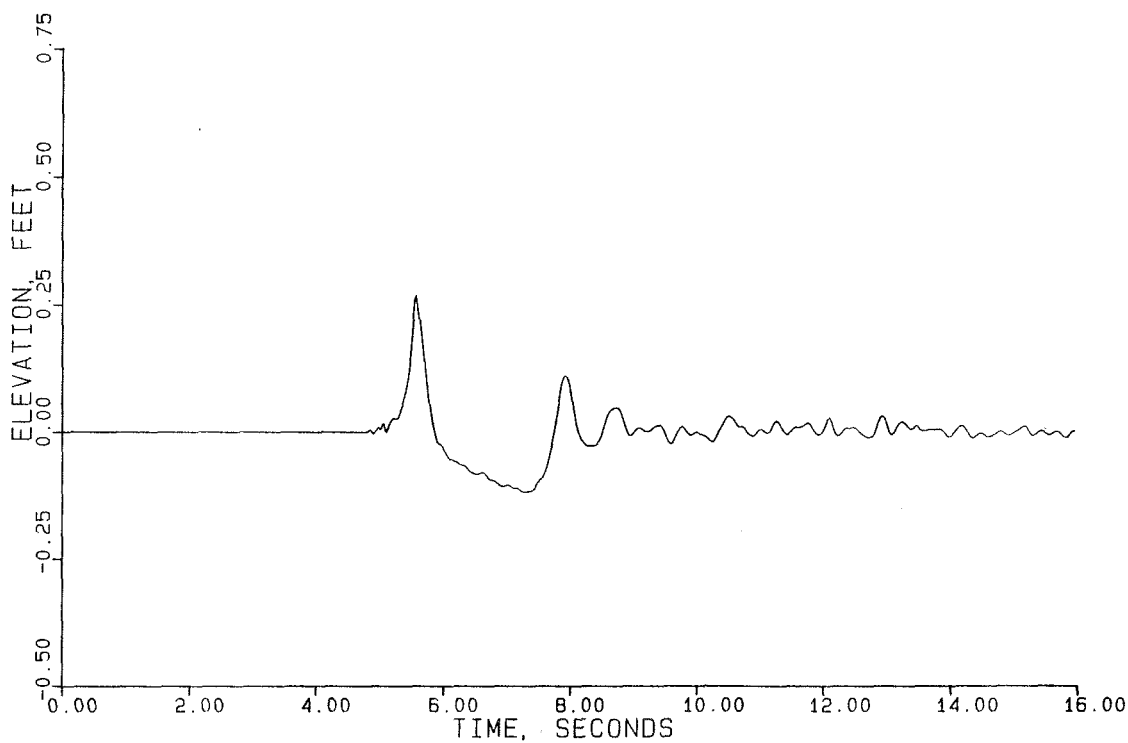
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 3



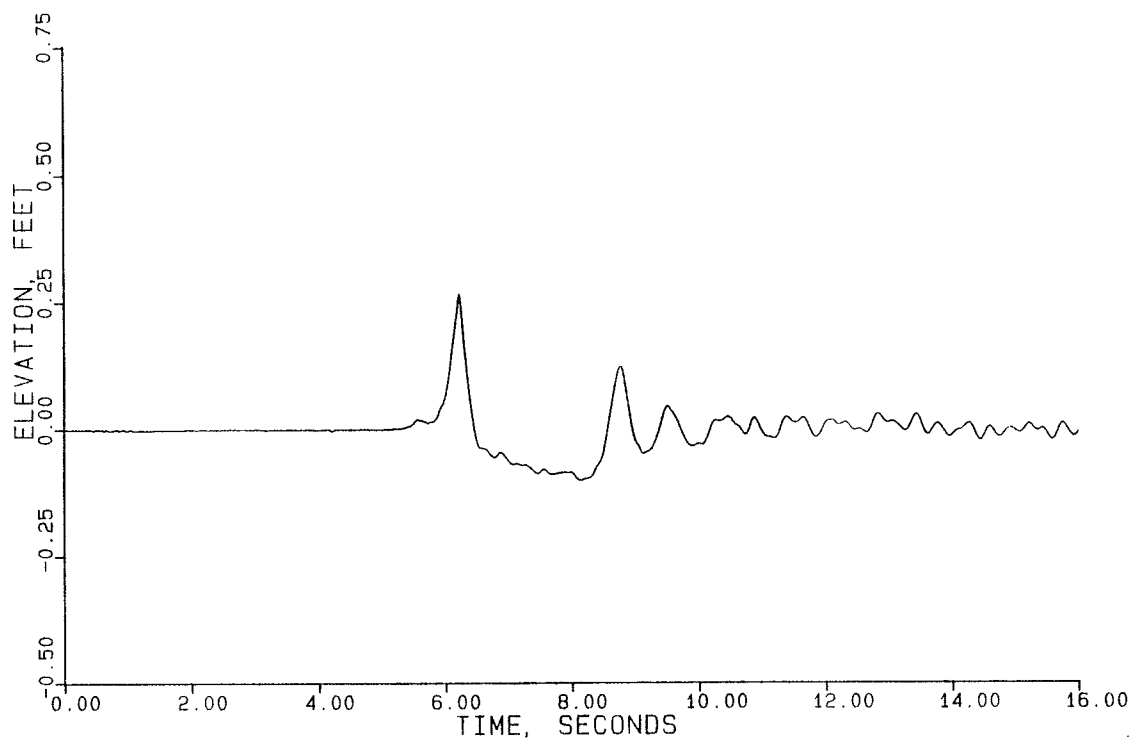
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 4



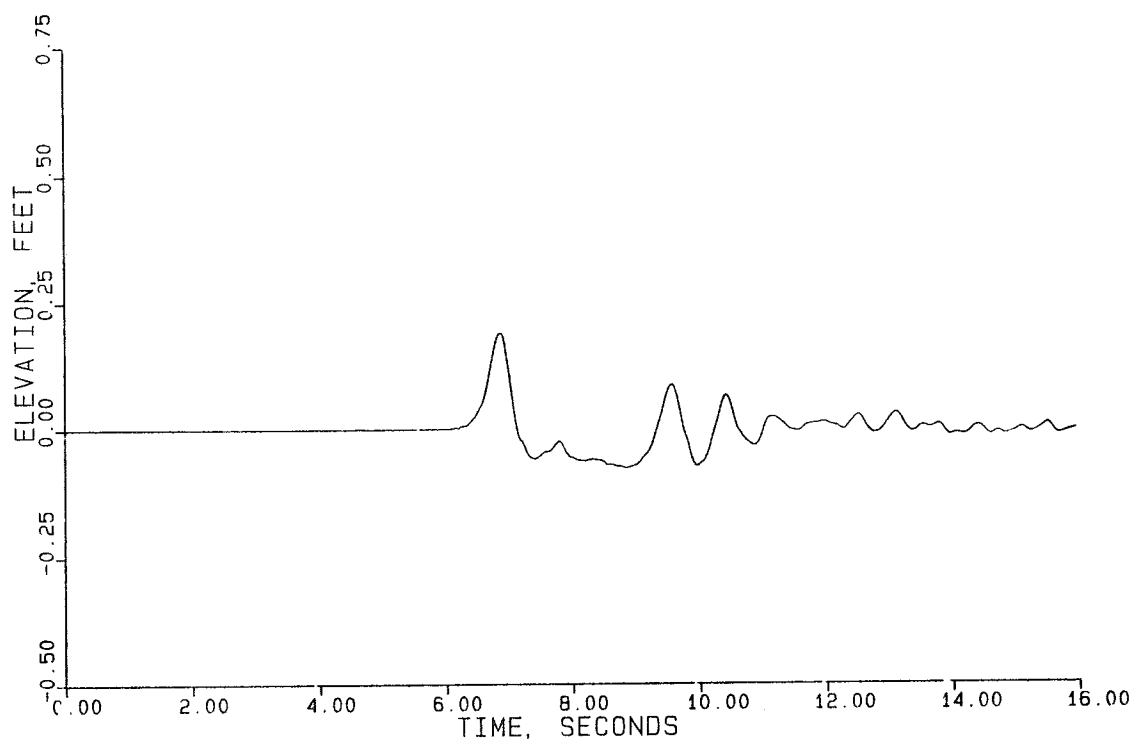
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 5



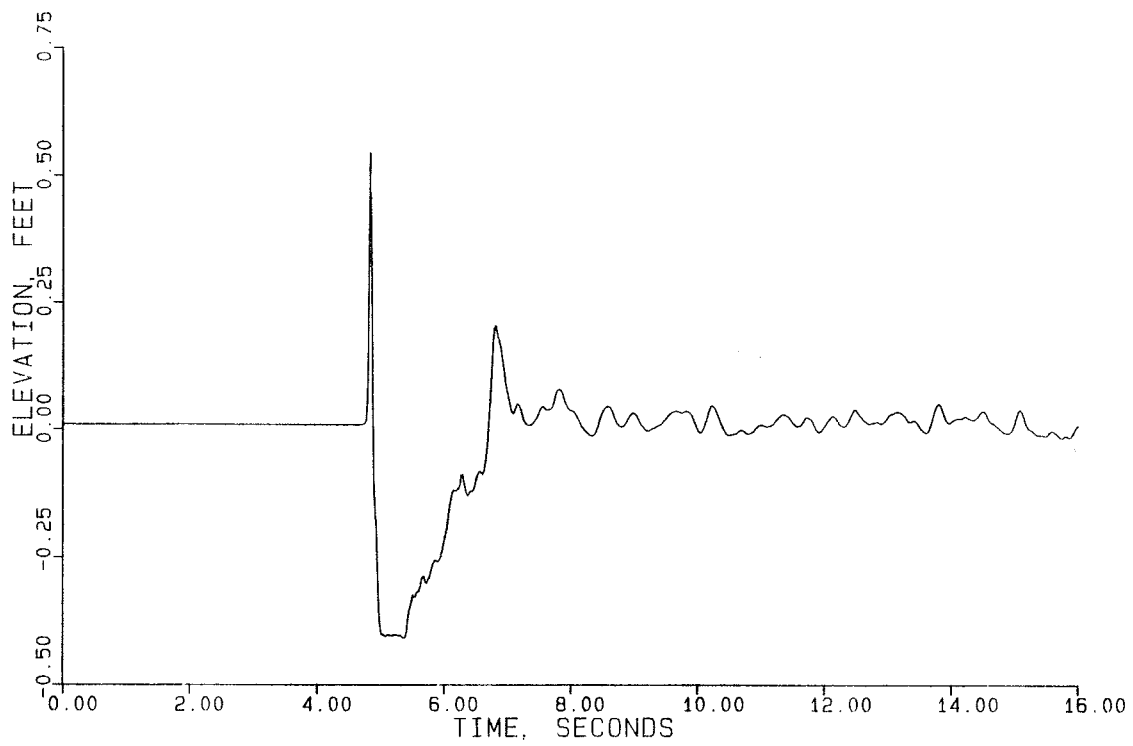
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 6



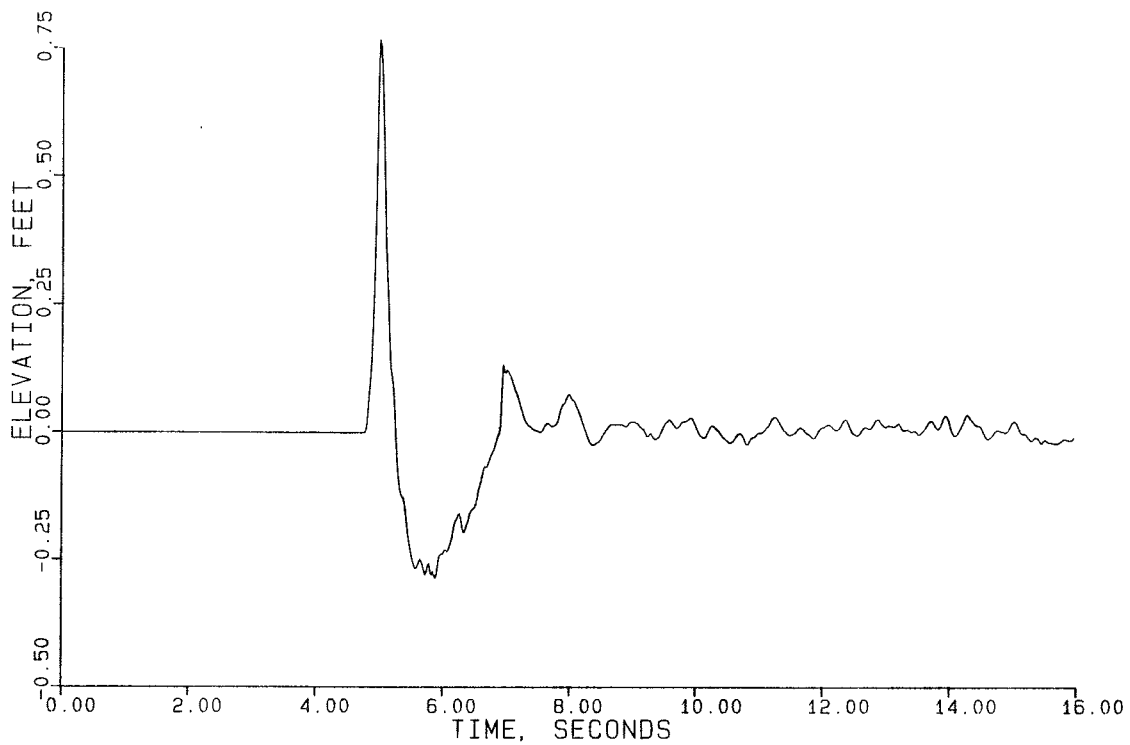
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 7



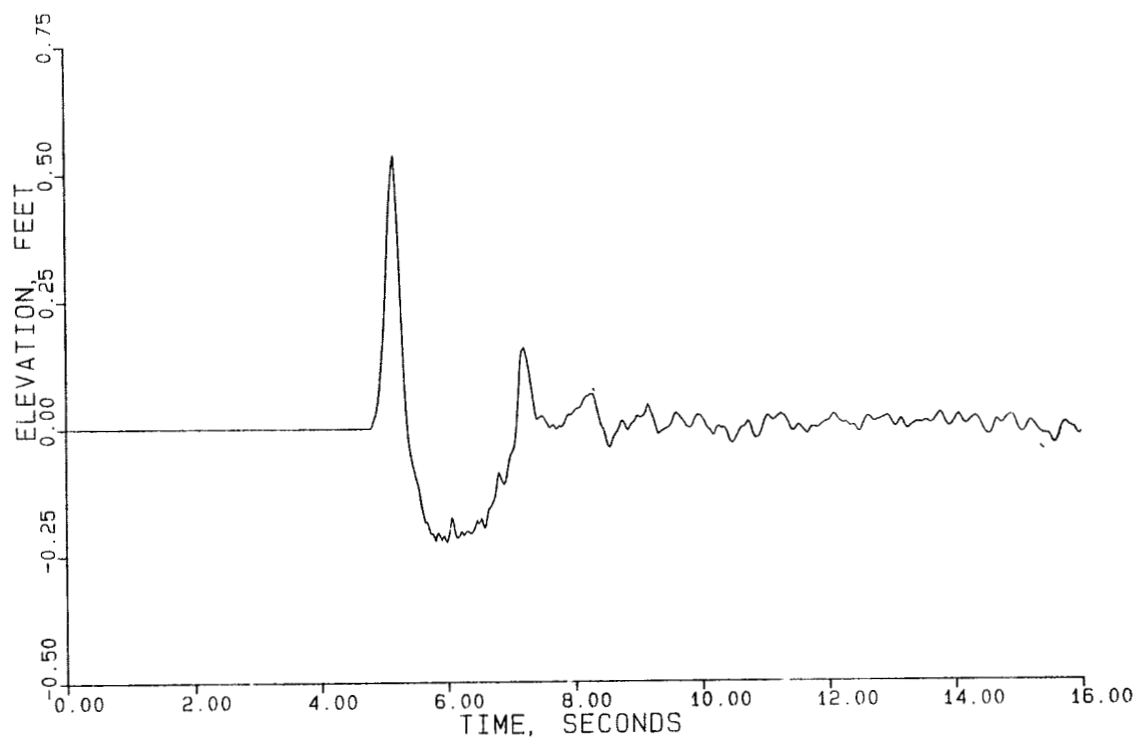
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 11, GAGE 8



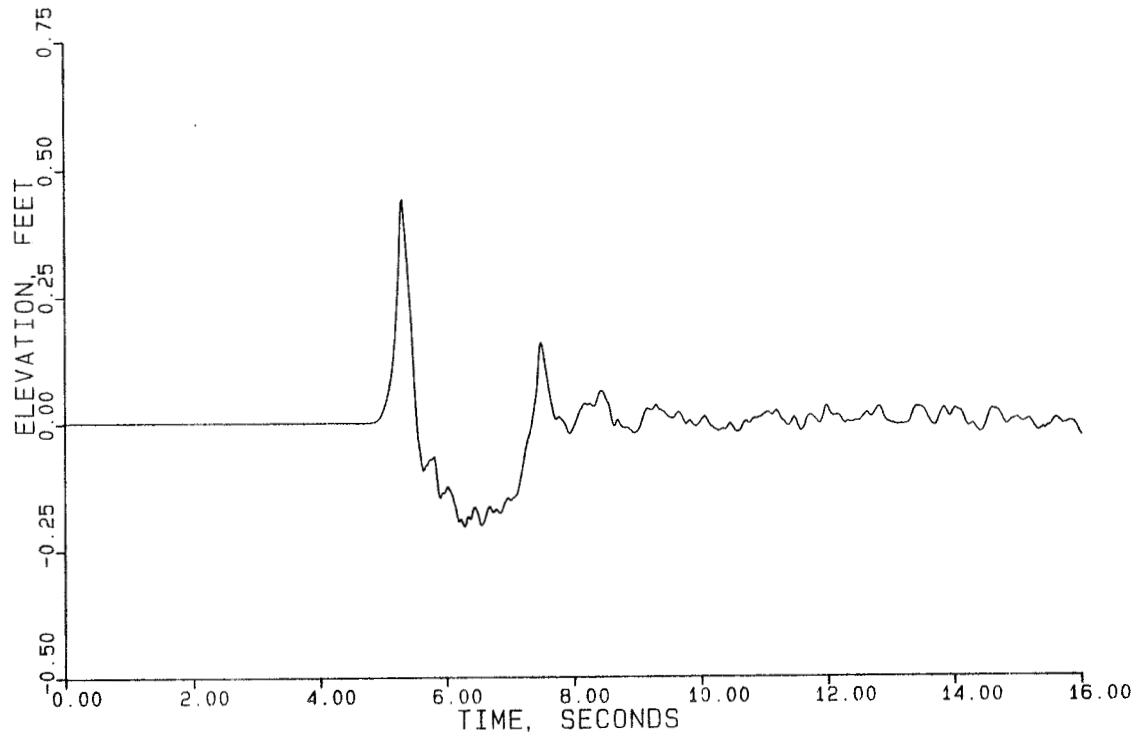
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 1



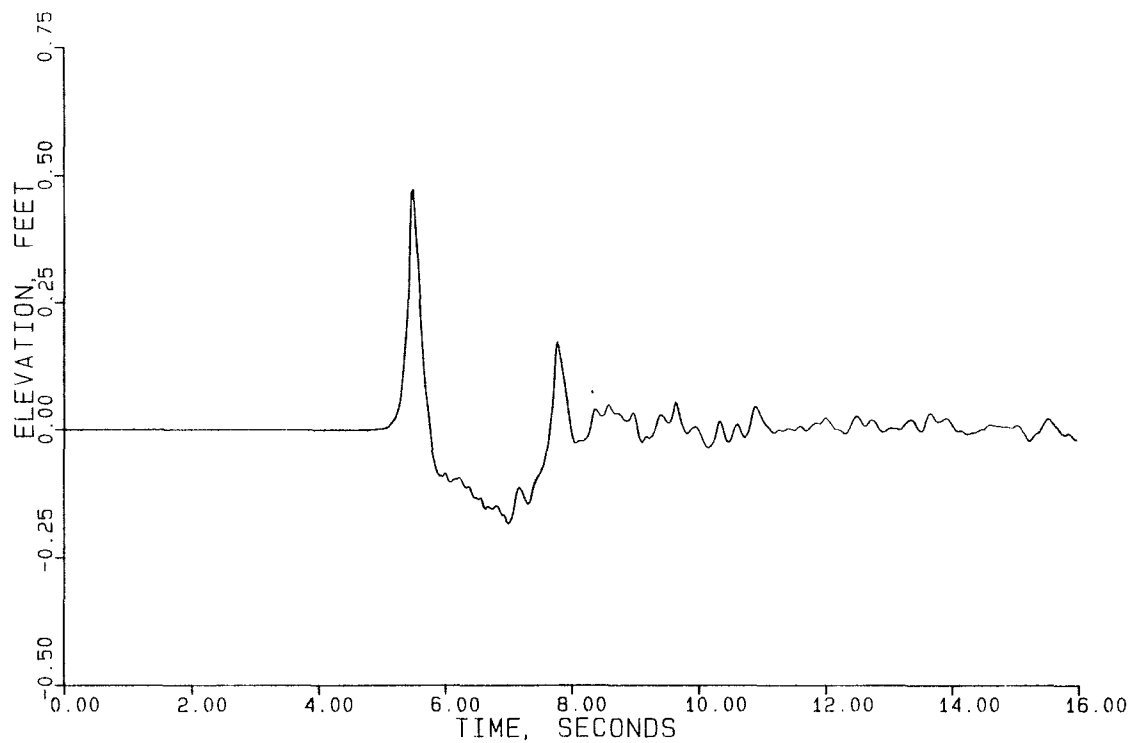
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 2



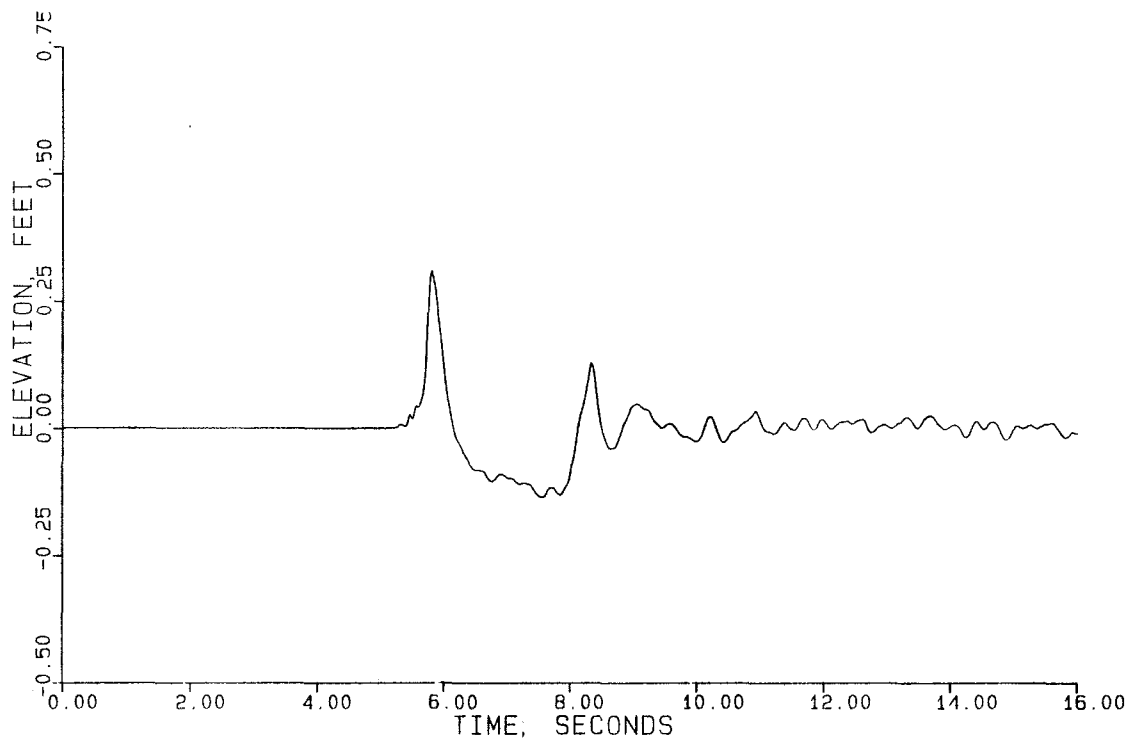
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 3



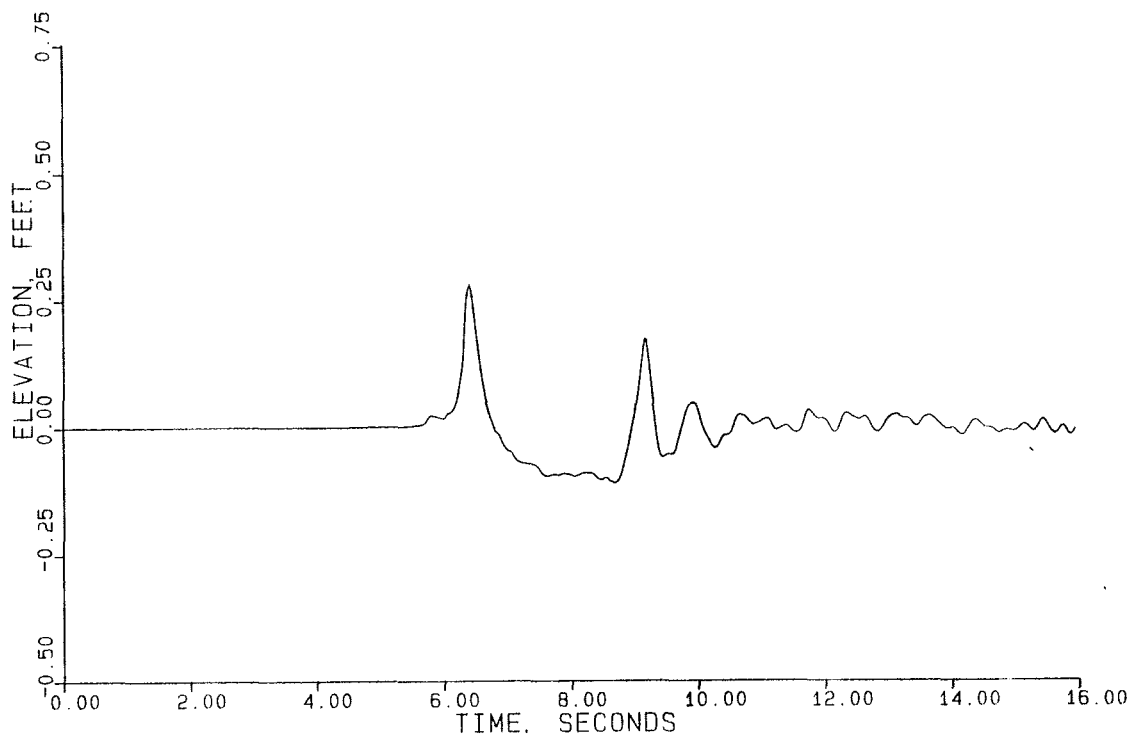
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 4



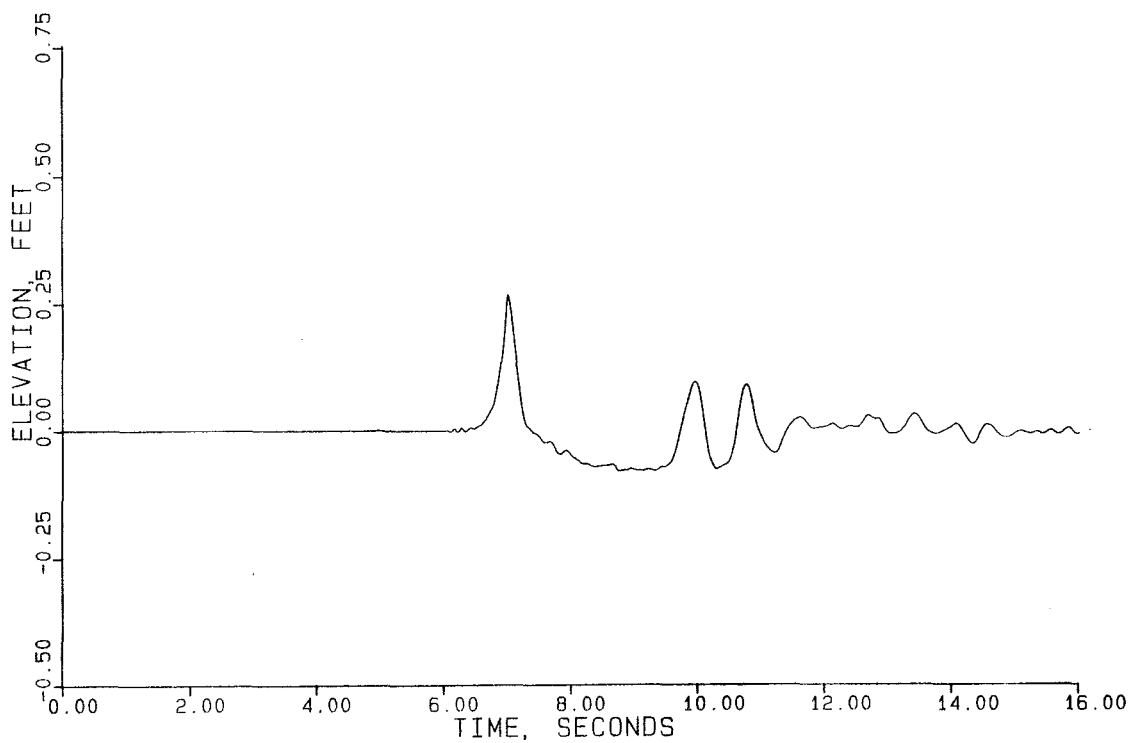
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 6

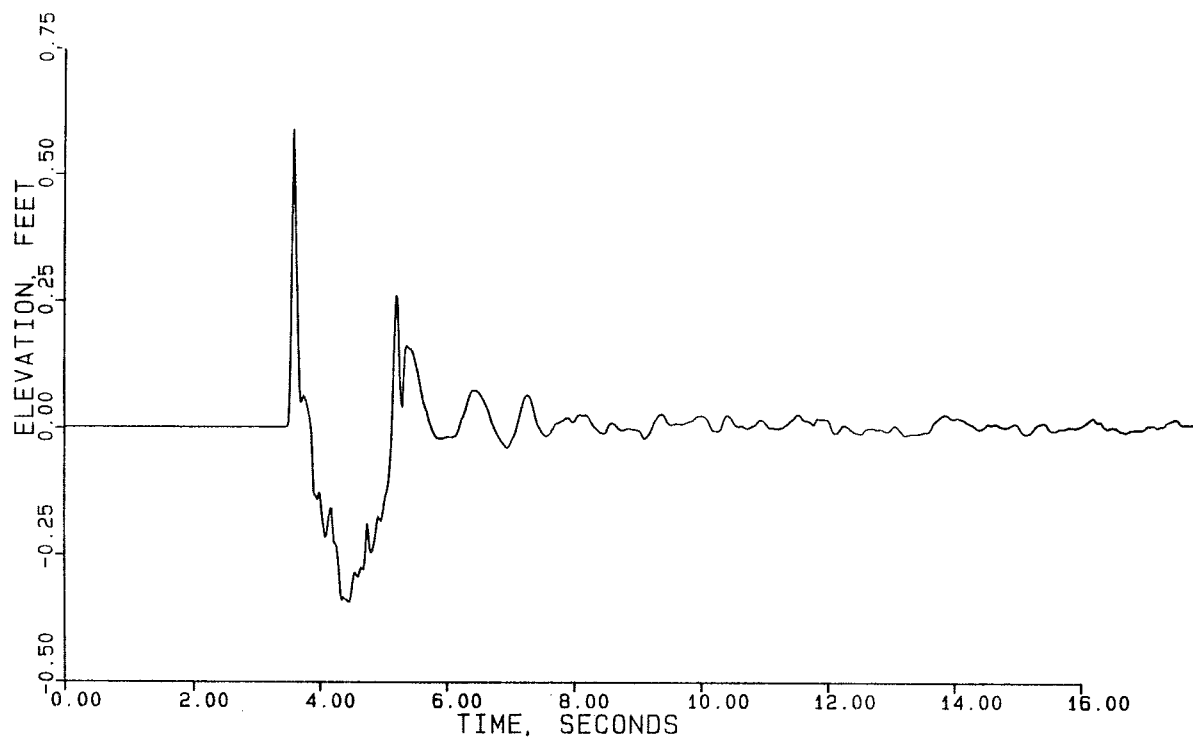


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 7

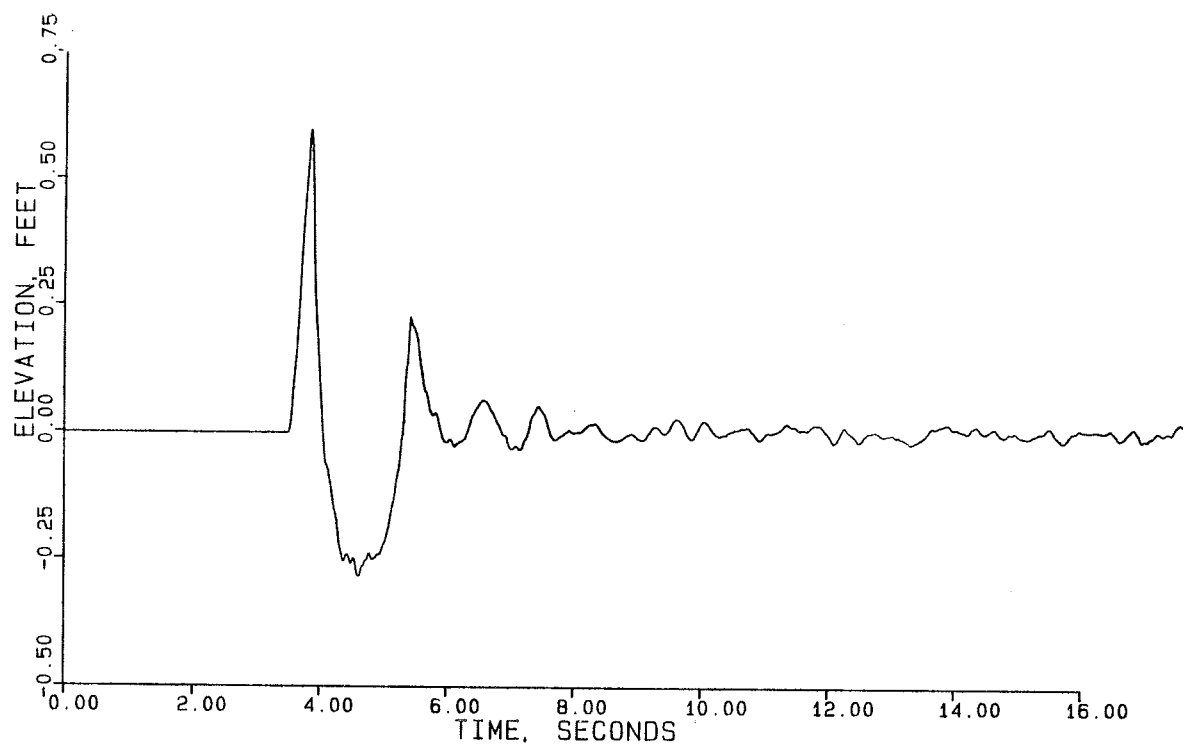


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 12, GAGE 8

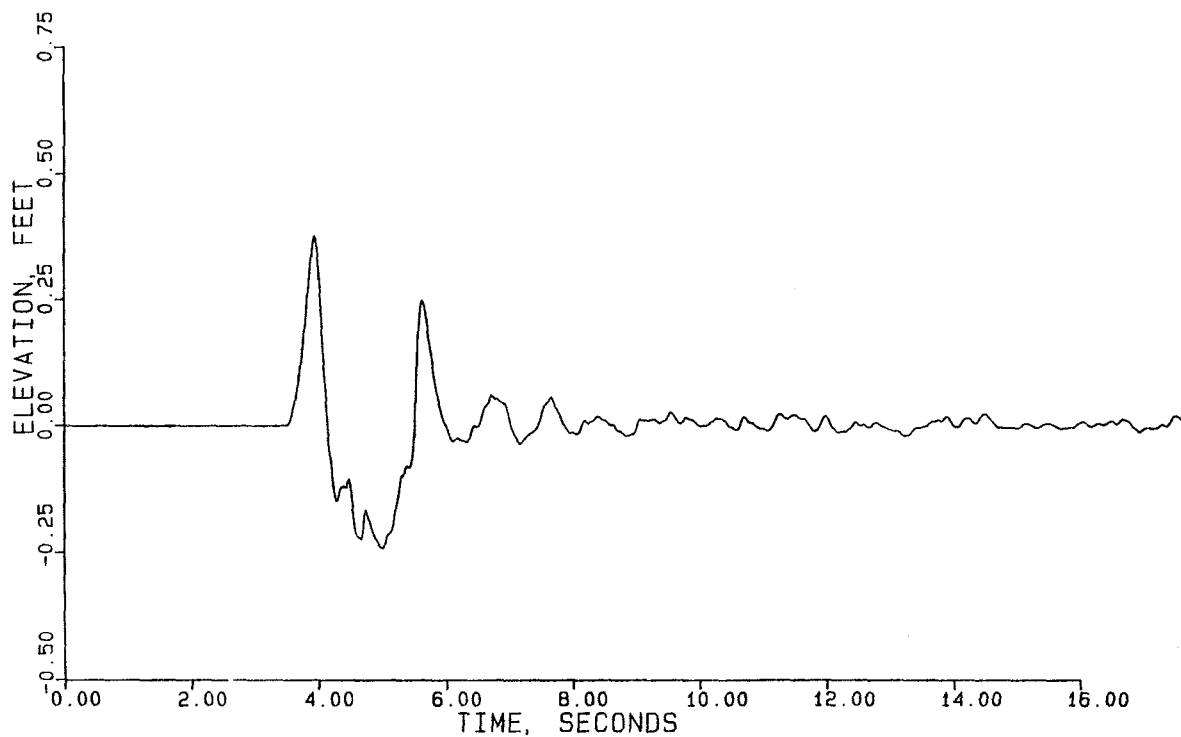




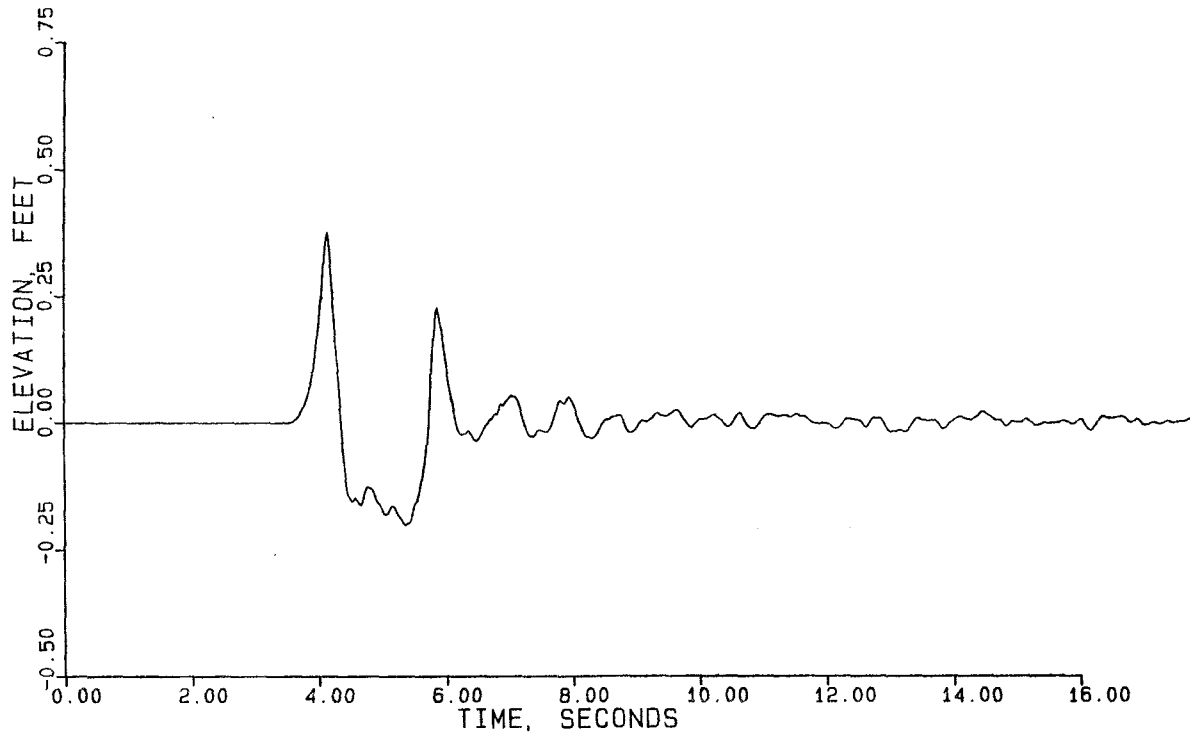
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 1



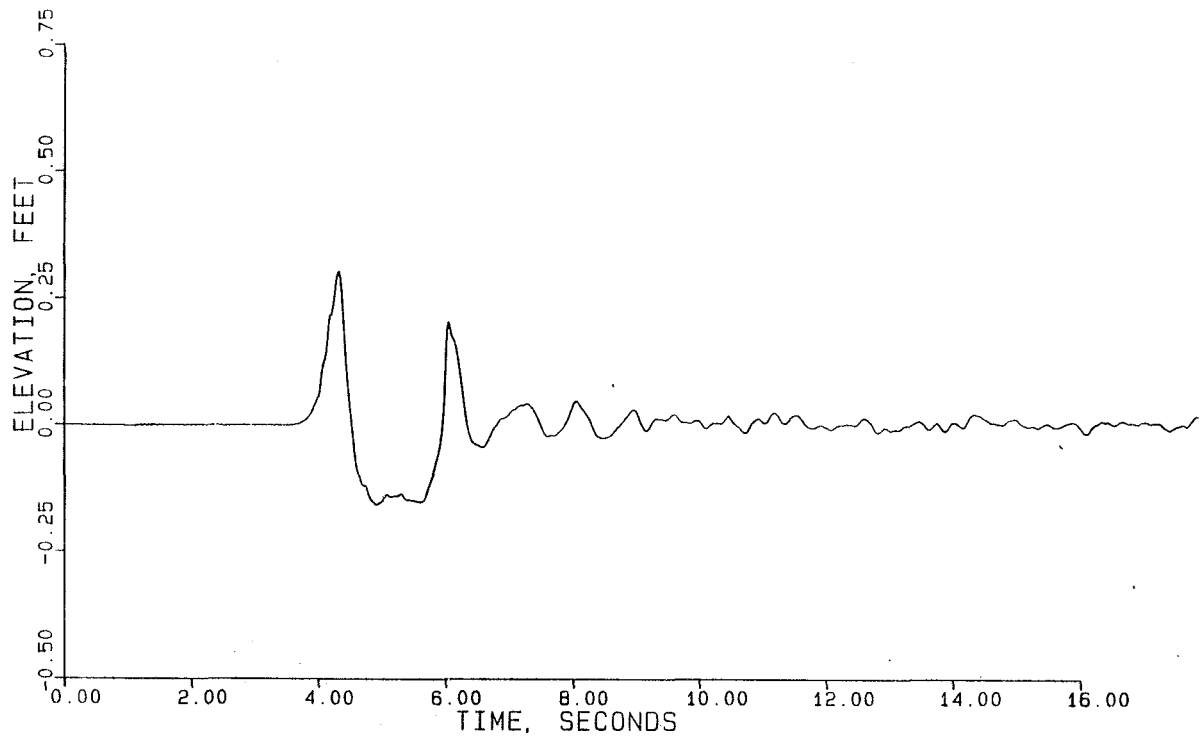
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 2



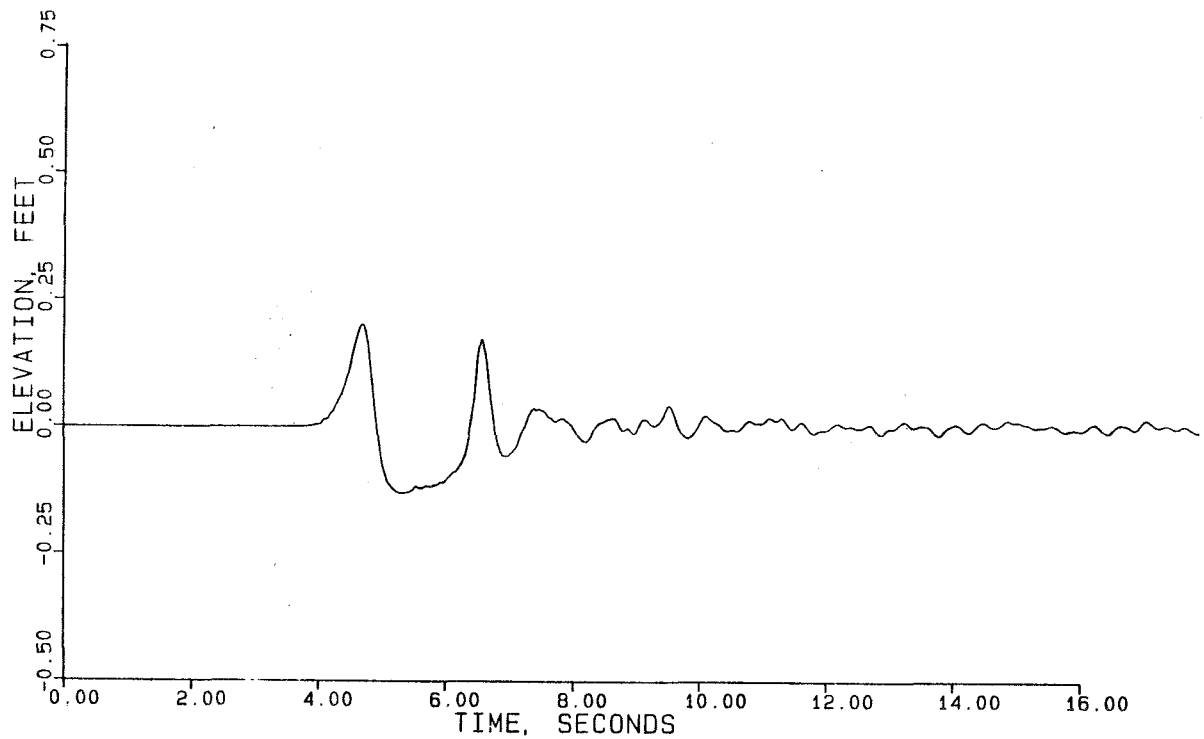
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 3



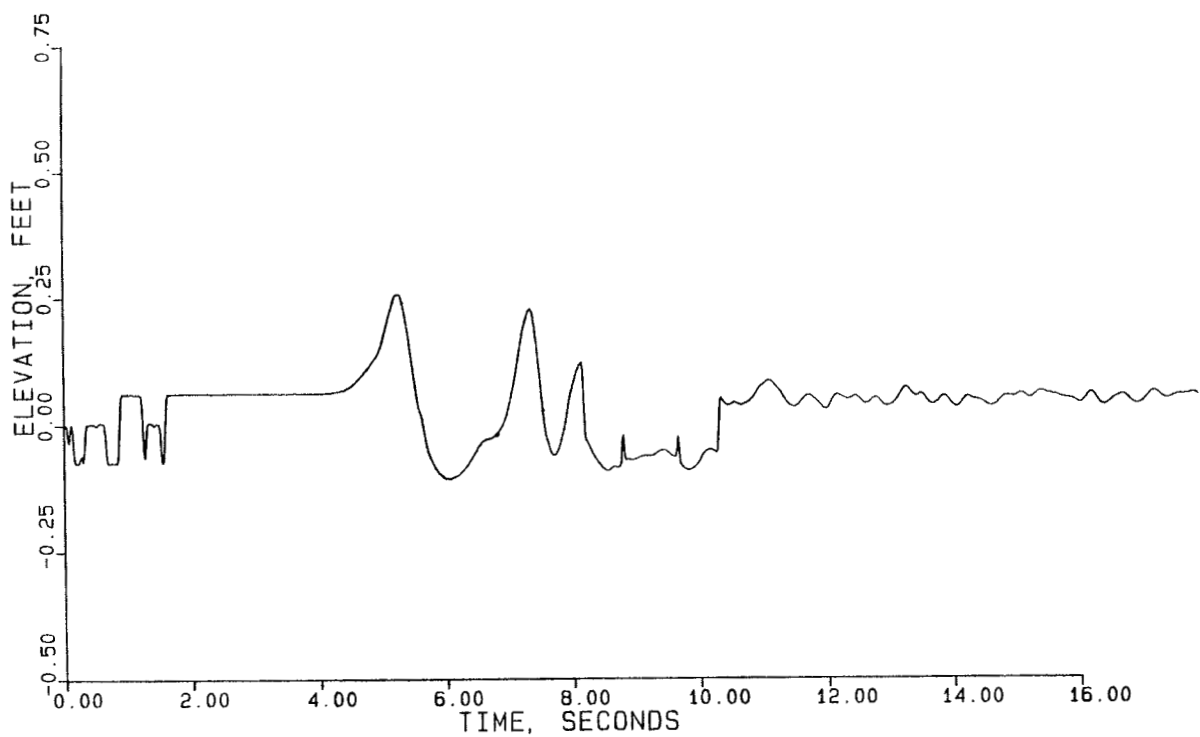
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 4



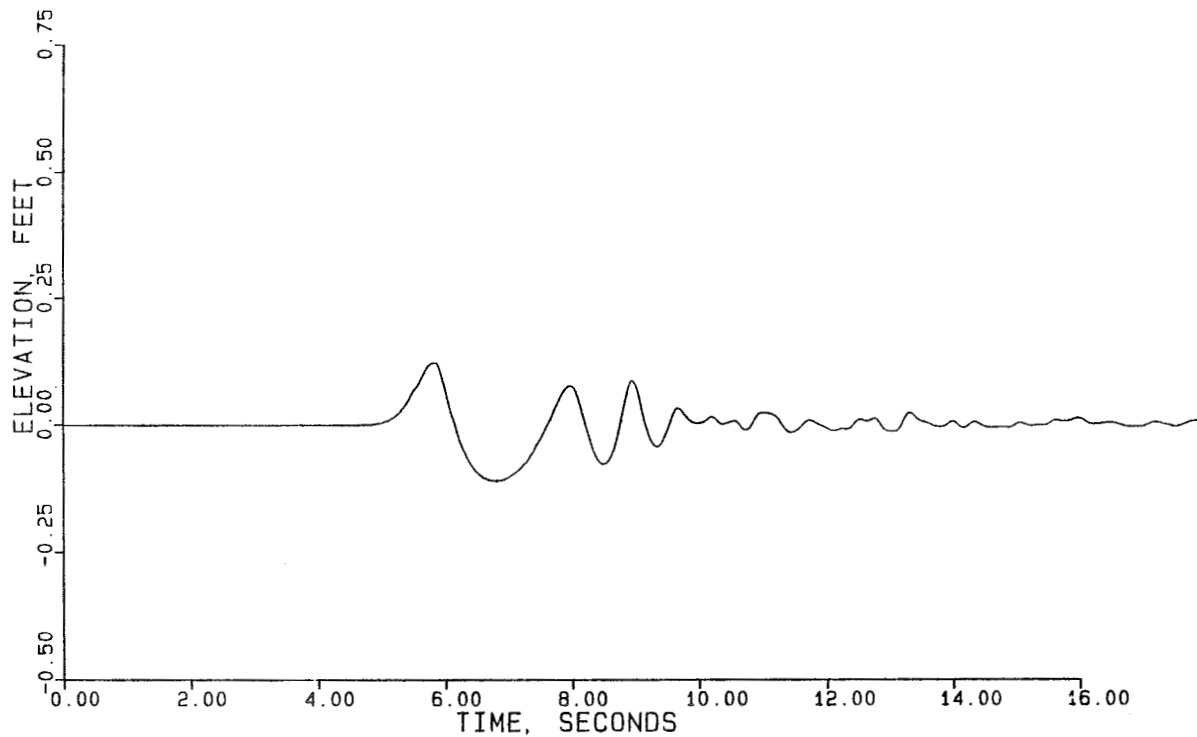
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 5



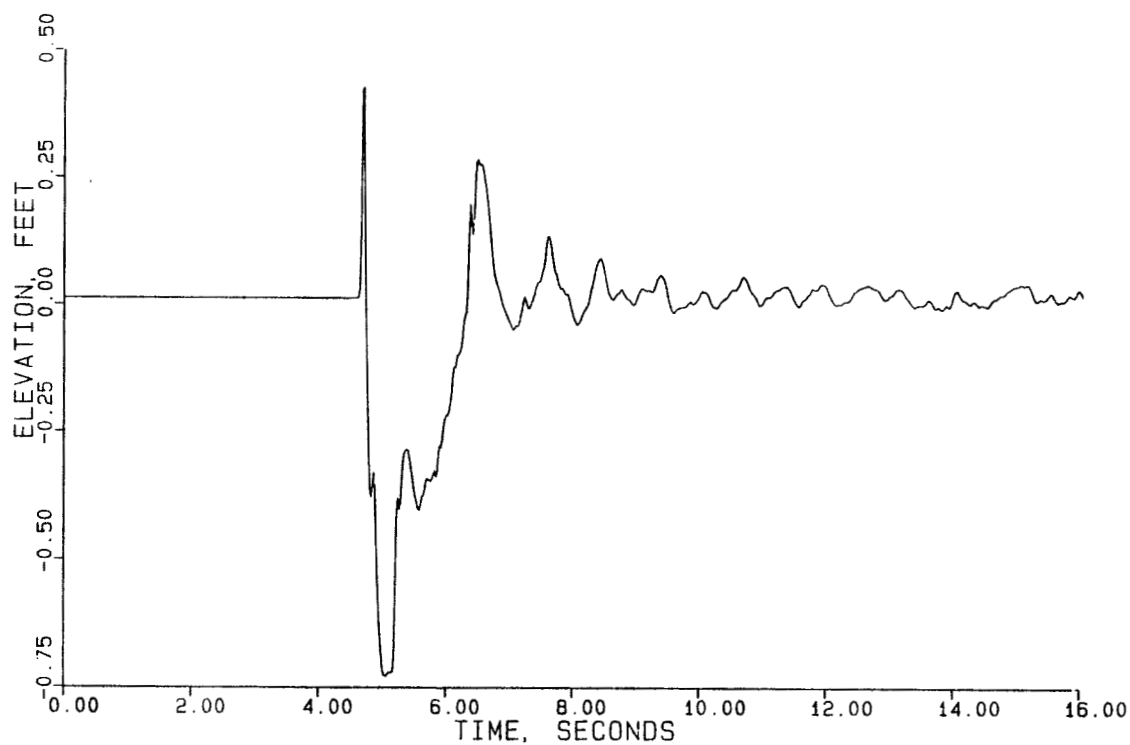
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 6



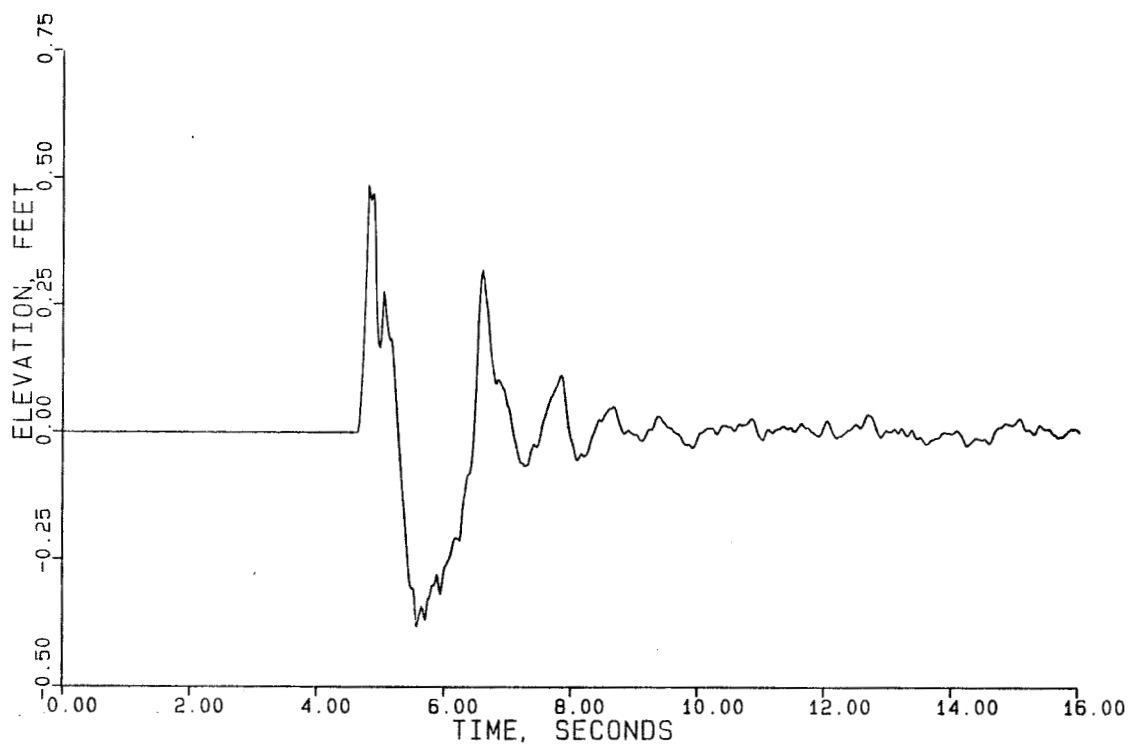
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 7



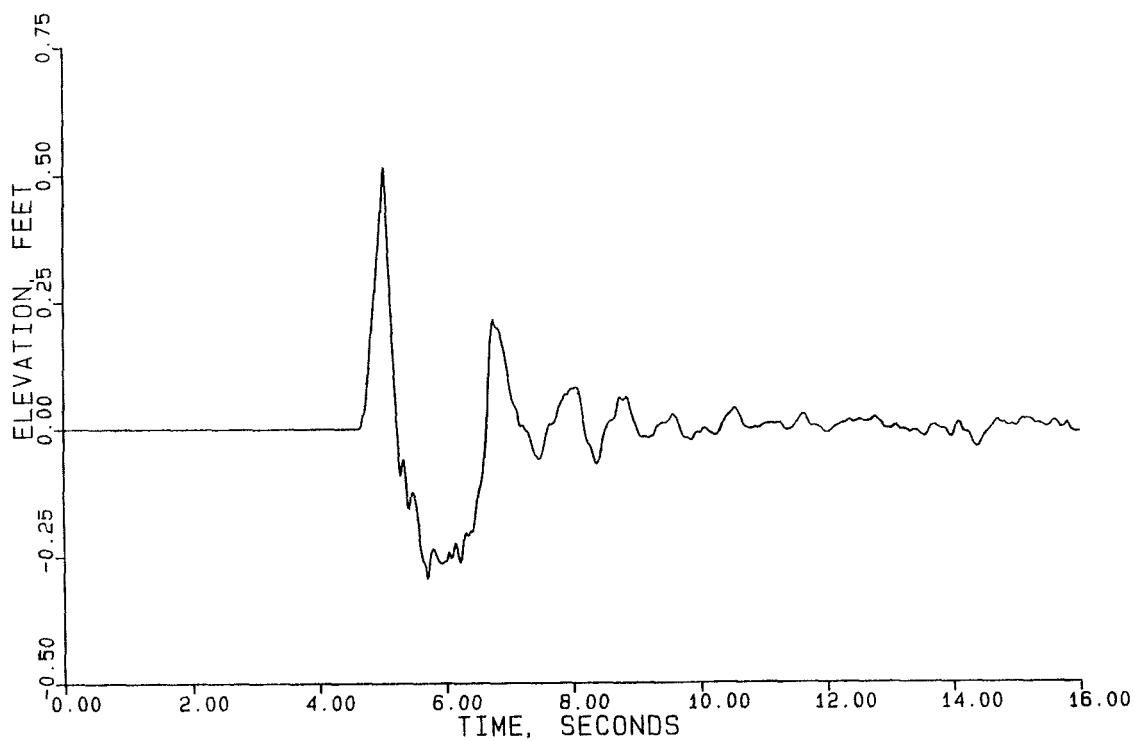
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 13, GAGE 8



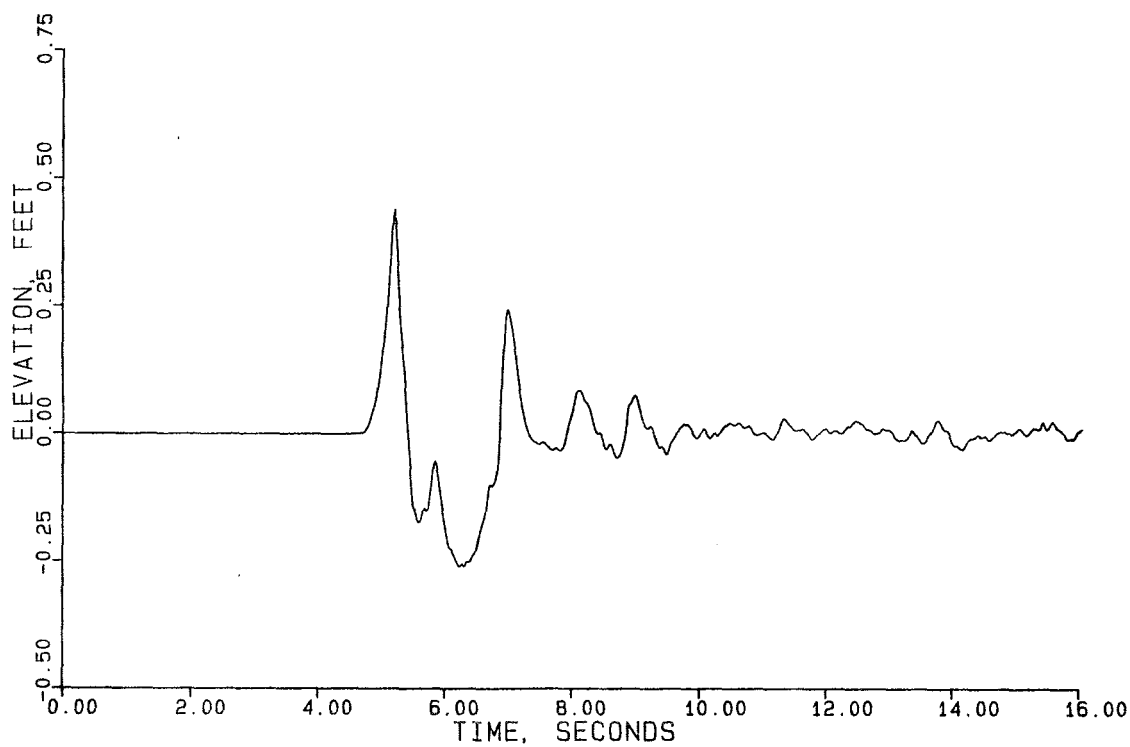
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 1



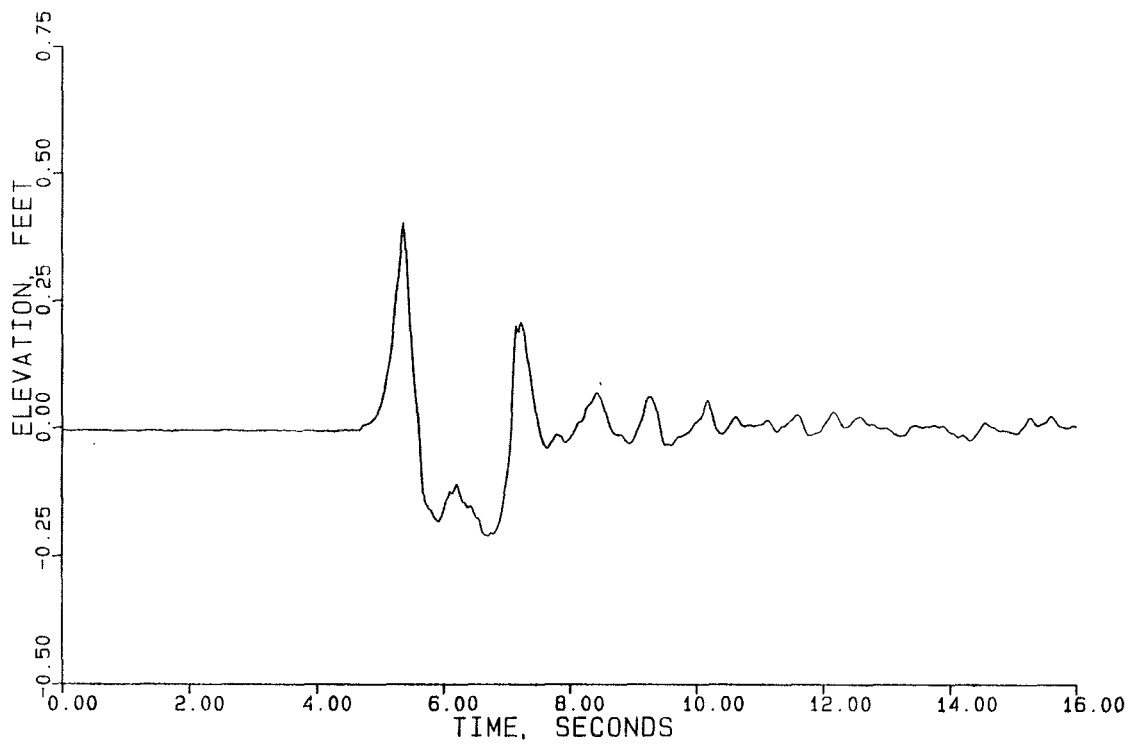
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 2



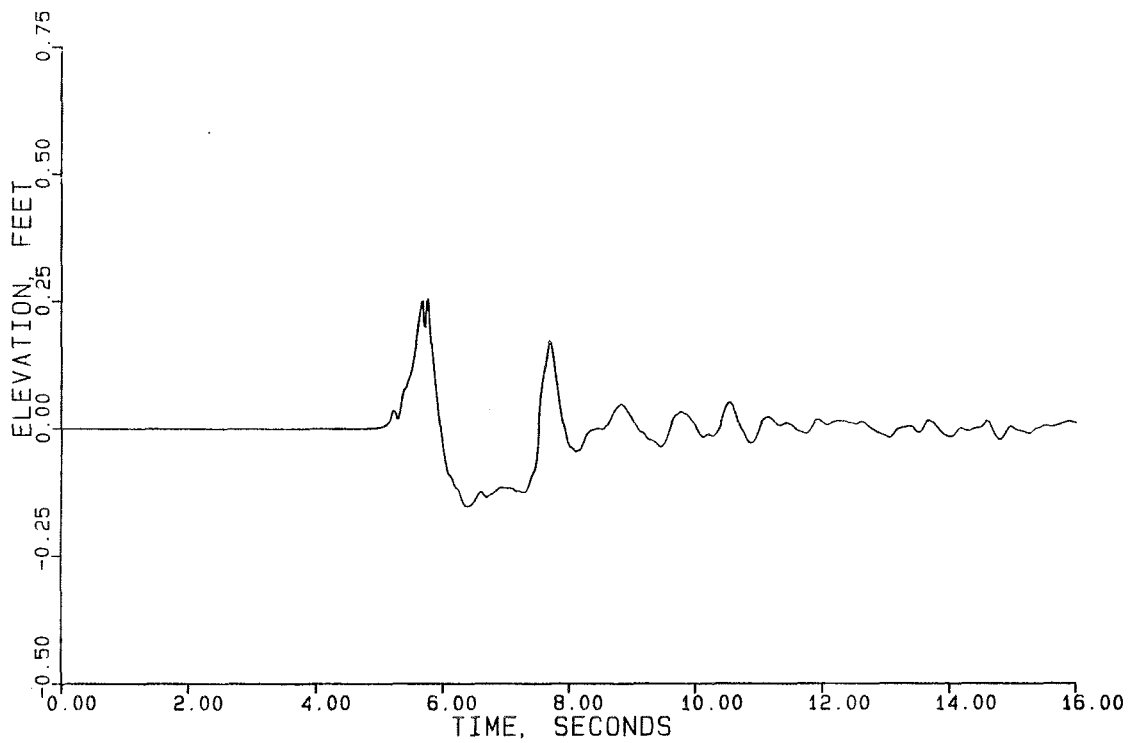
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 3



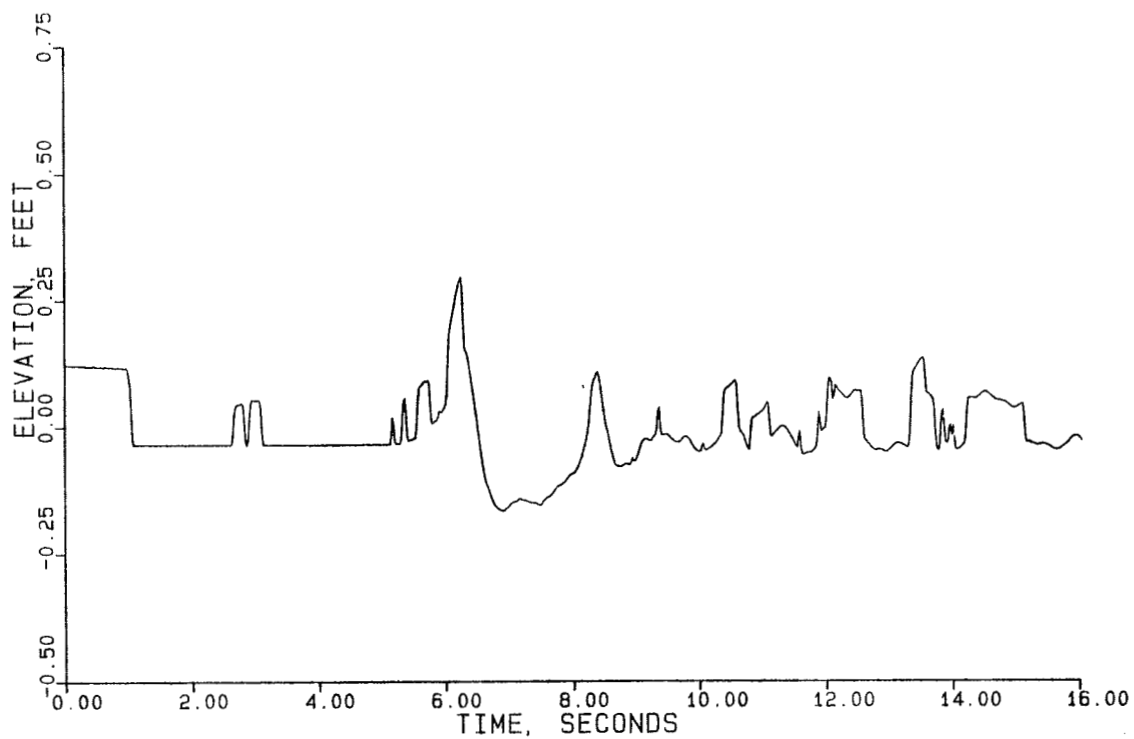
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 4



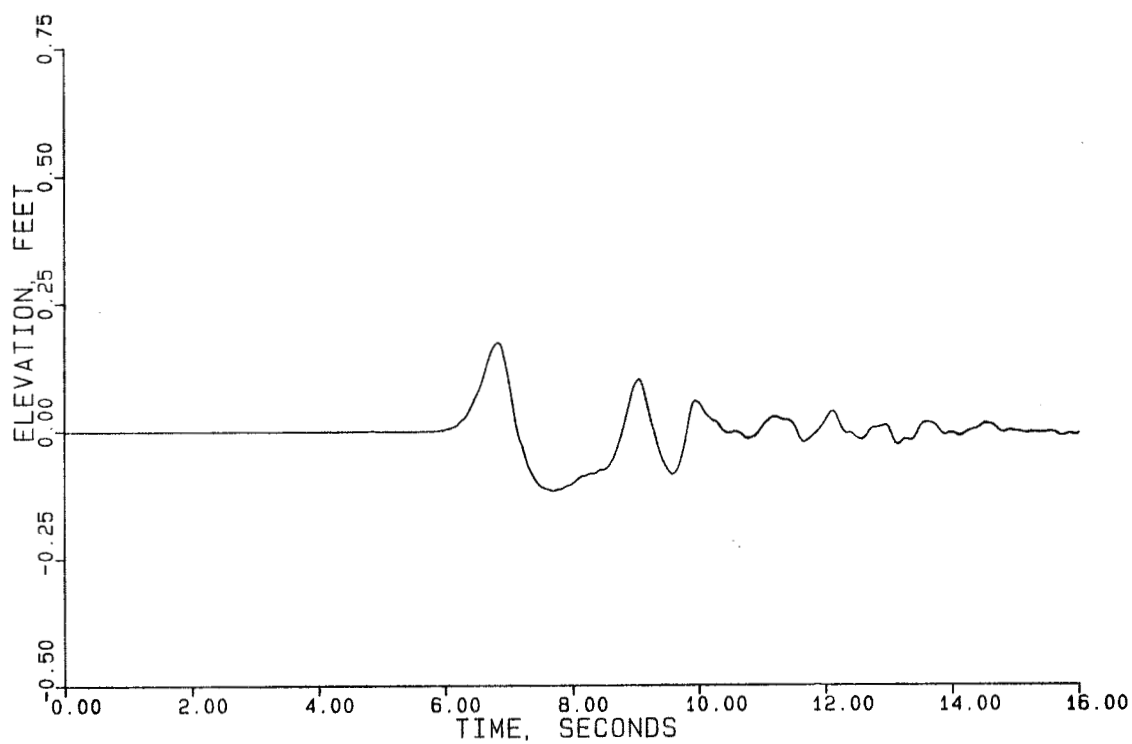
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 6

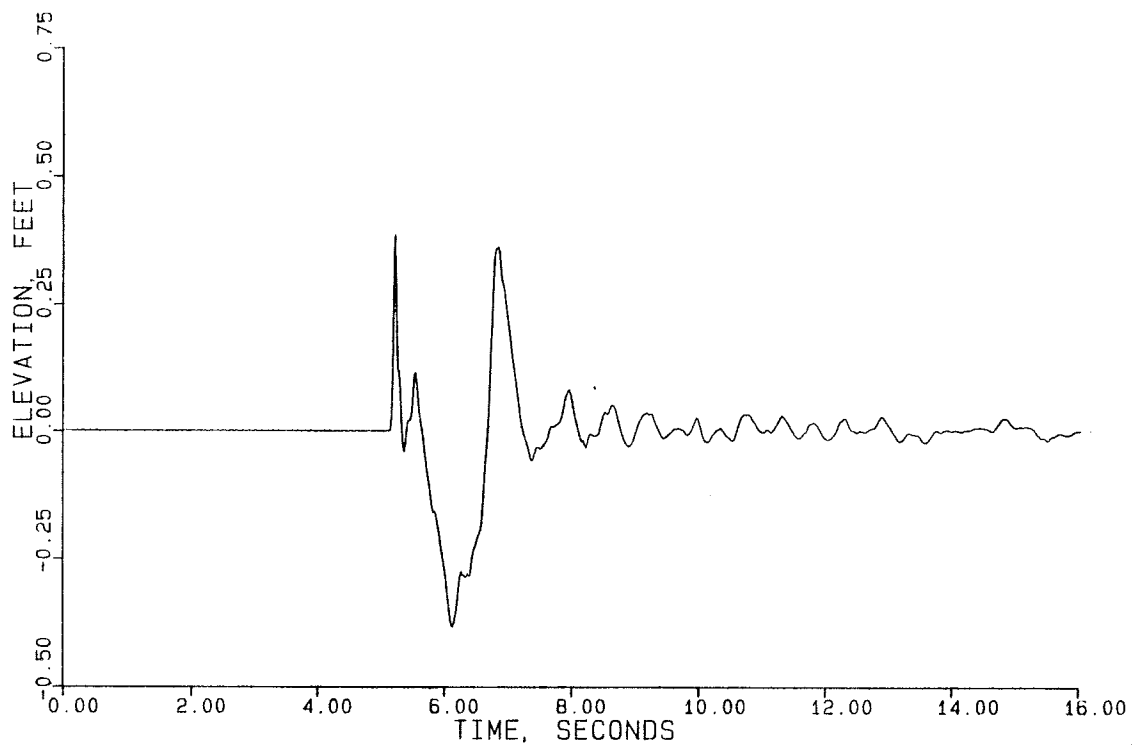


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 7

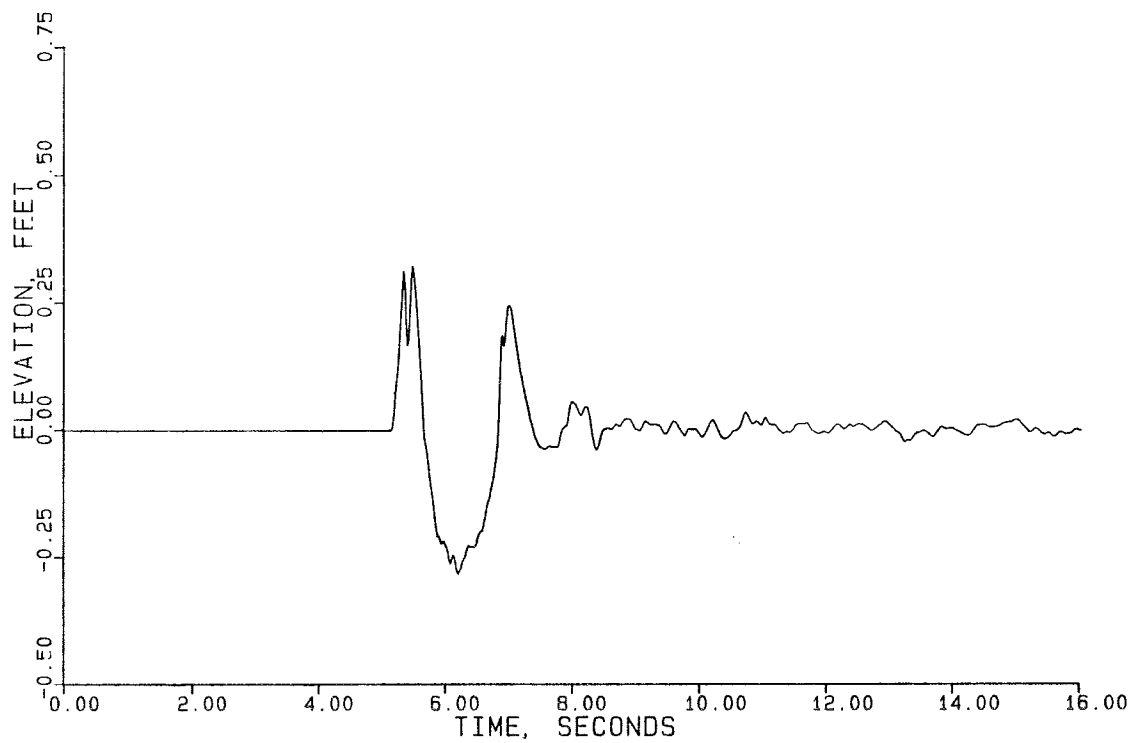


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 14, GAGE 8

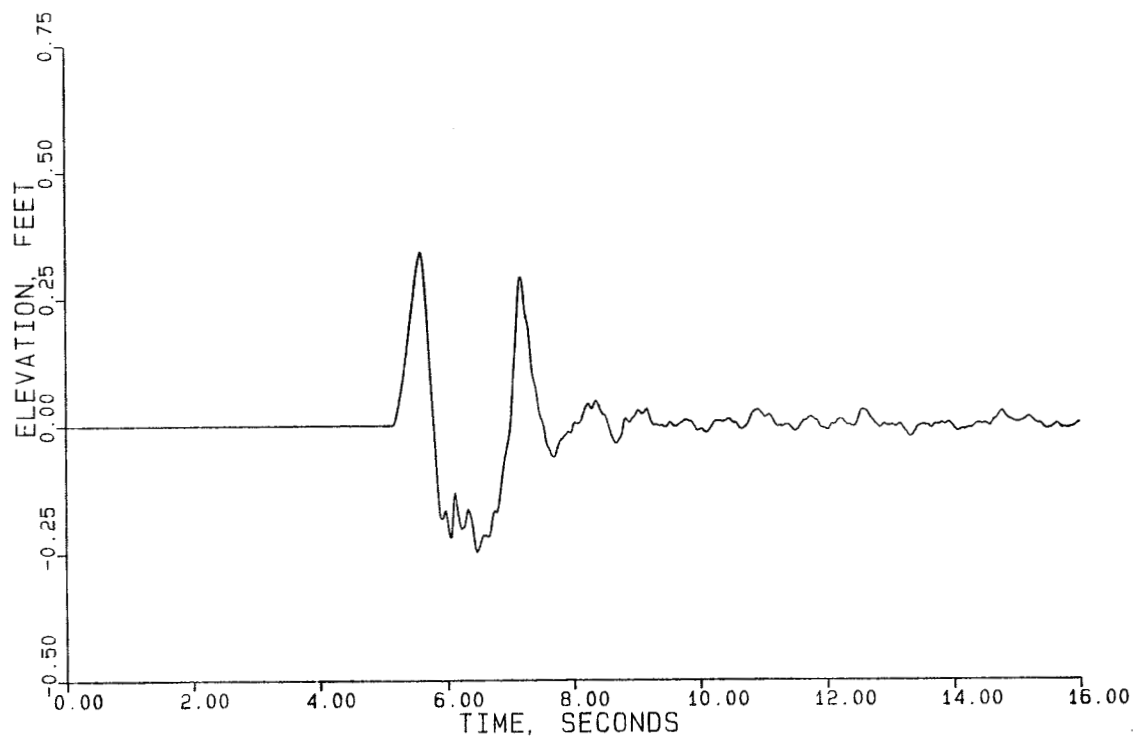




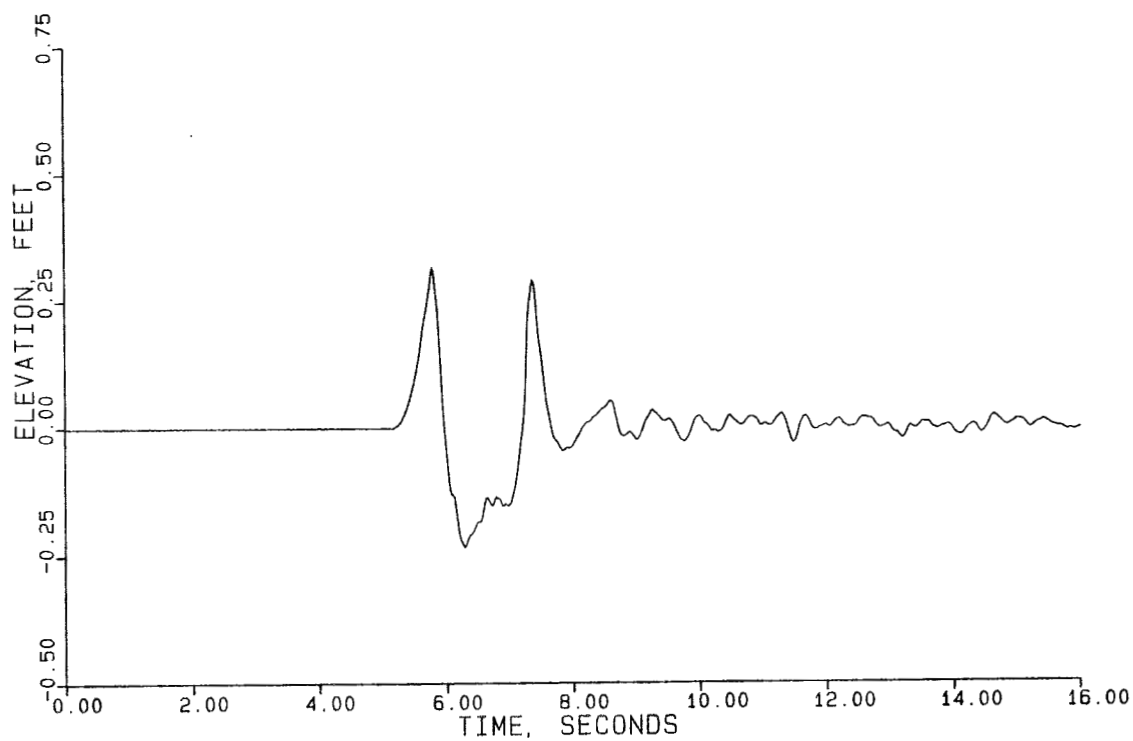
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 1



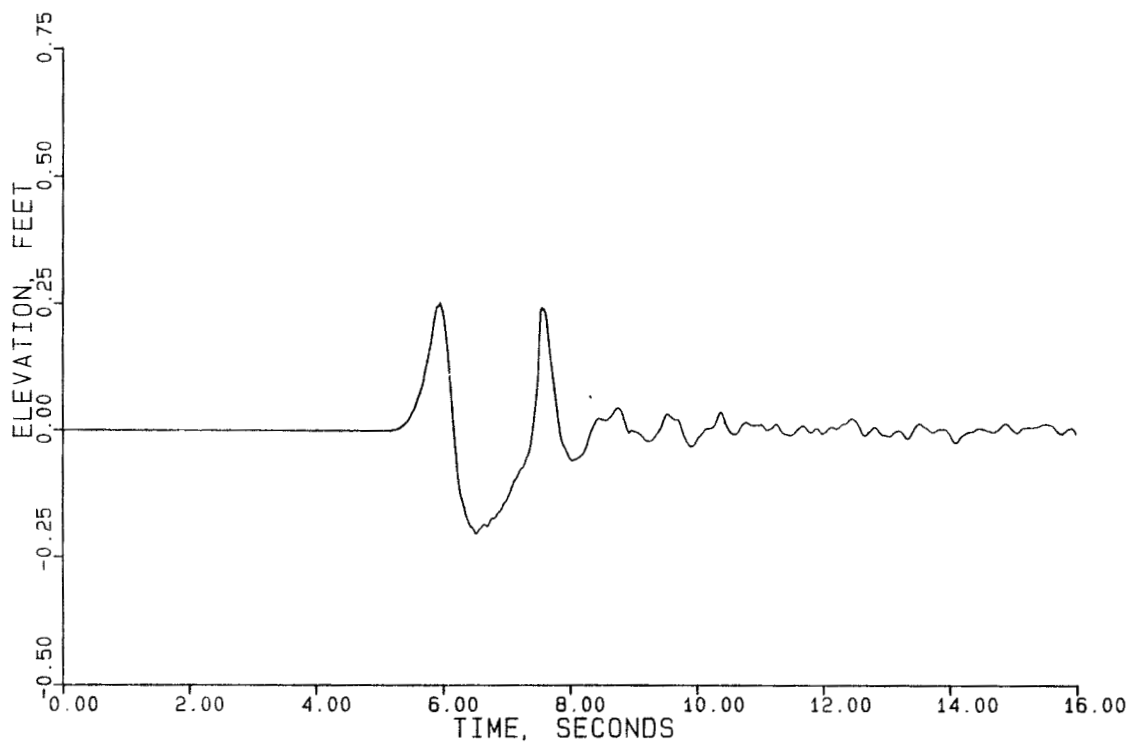
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 2



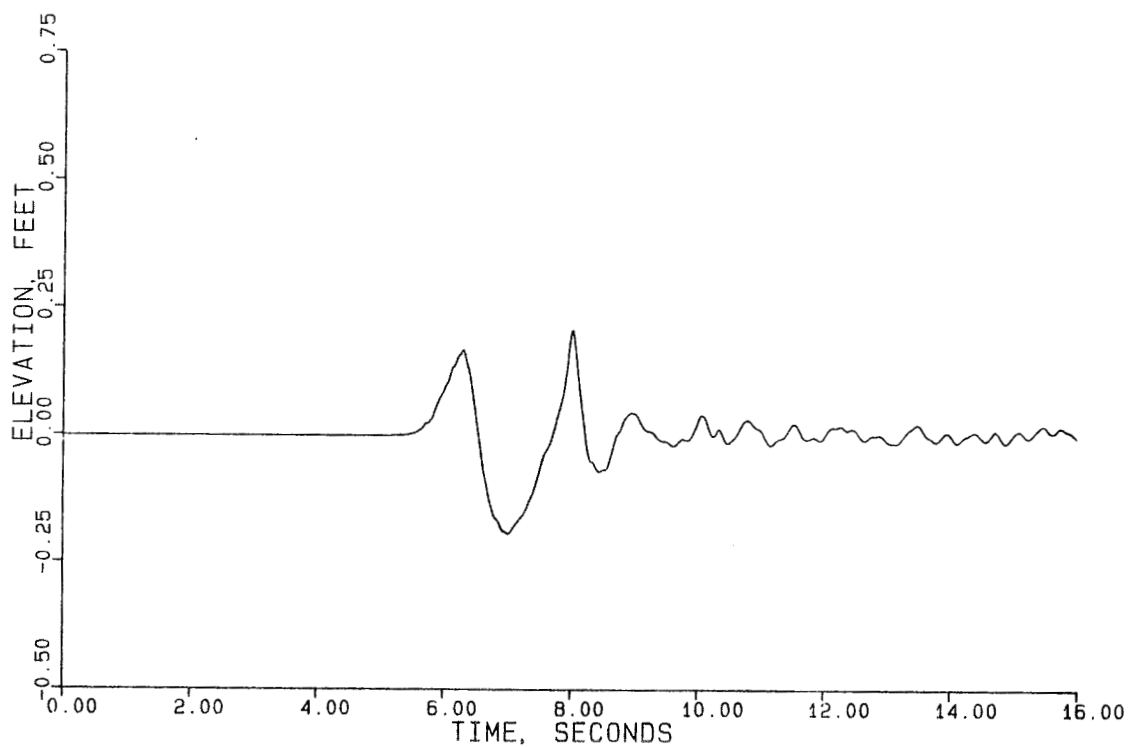
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 3



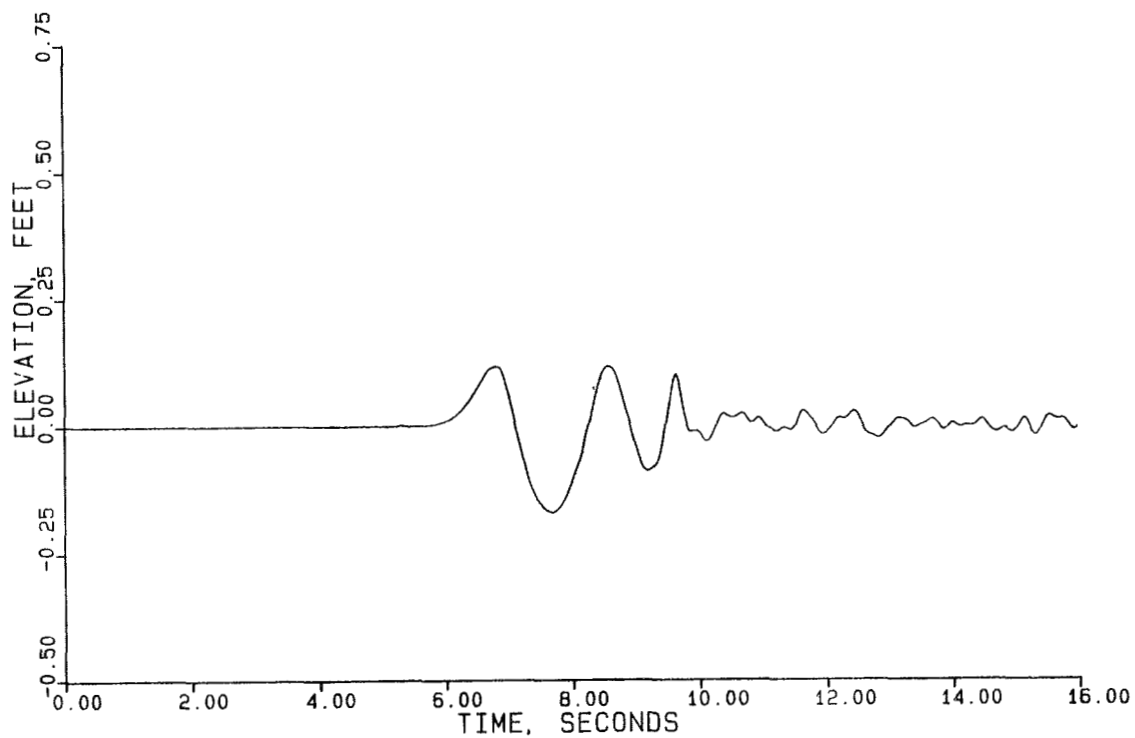
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 4



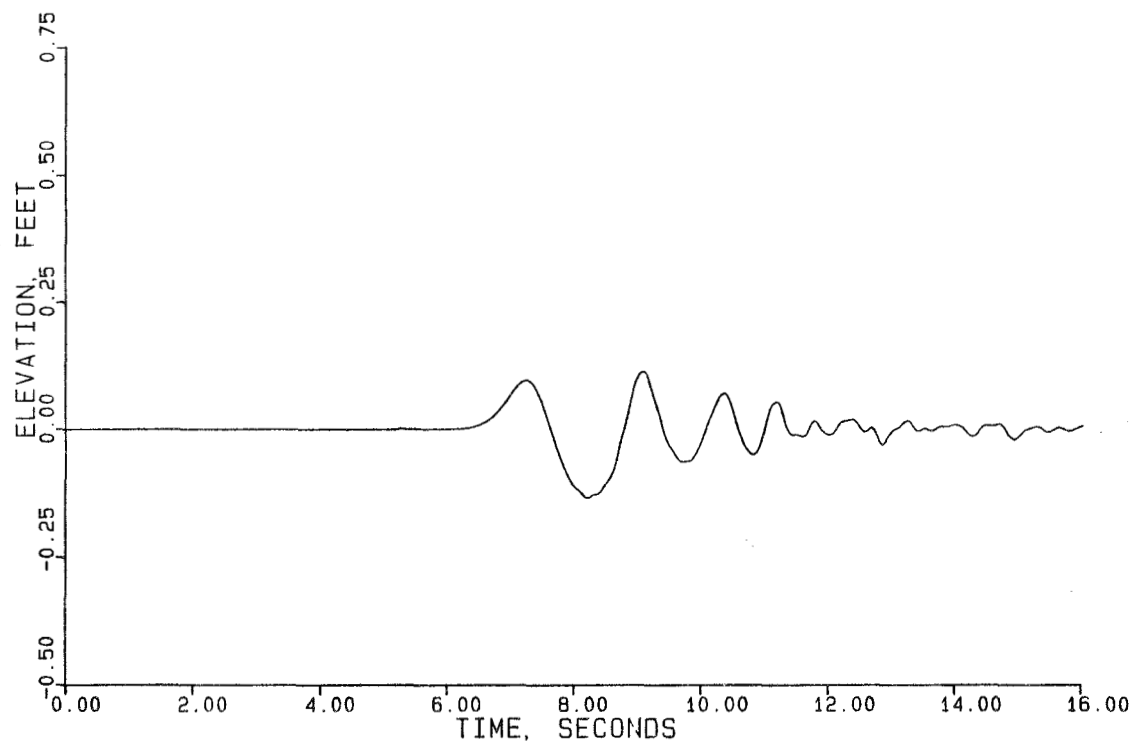
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 5



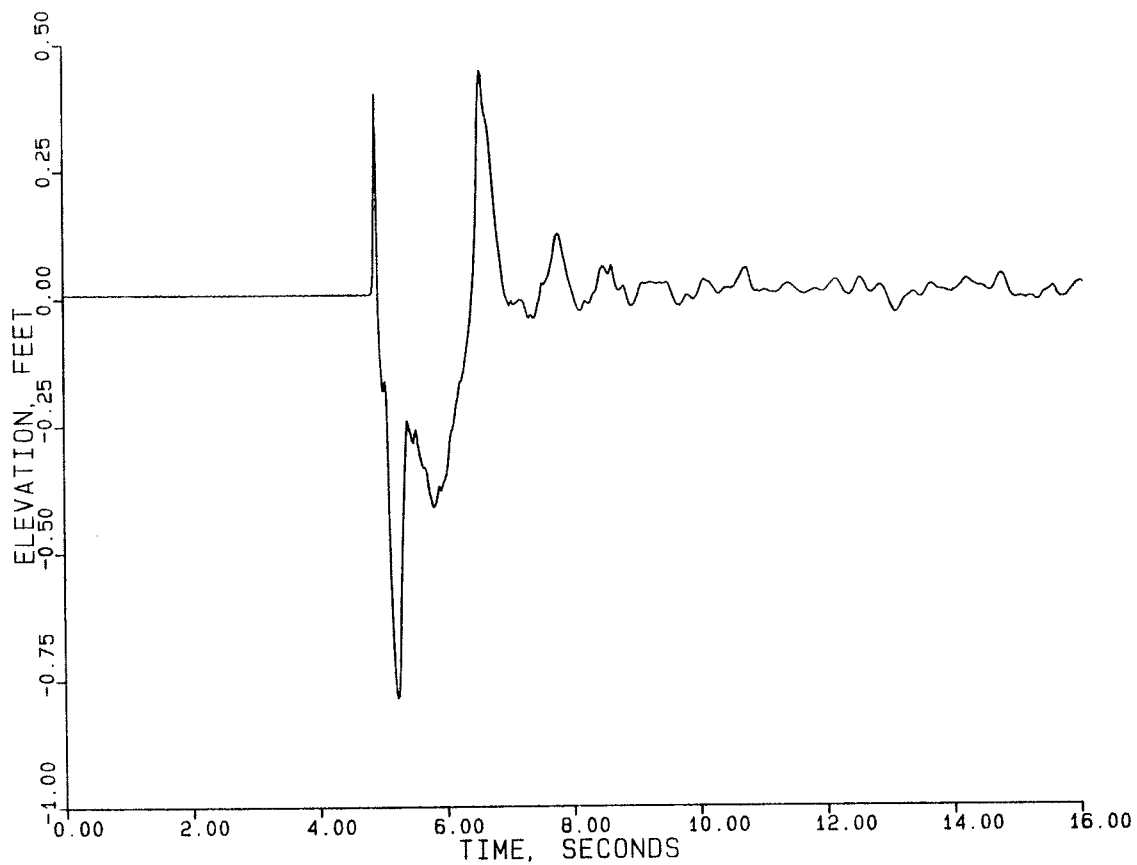
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 6



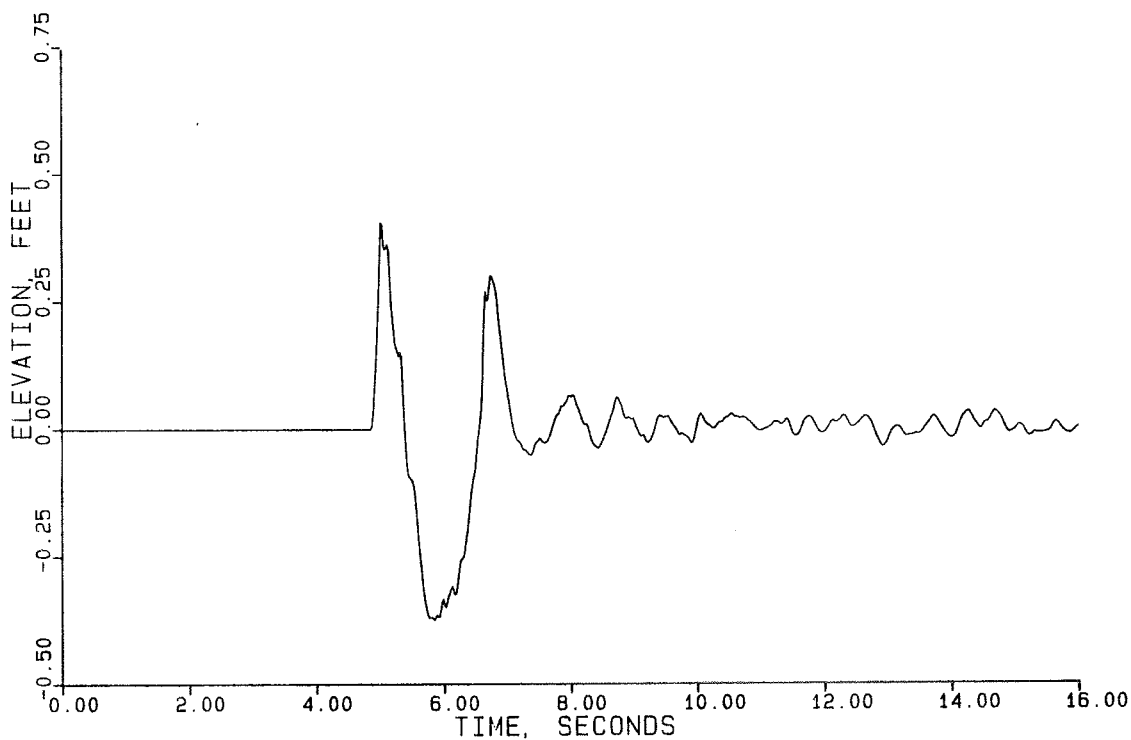
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 7



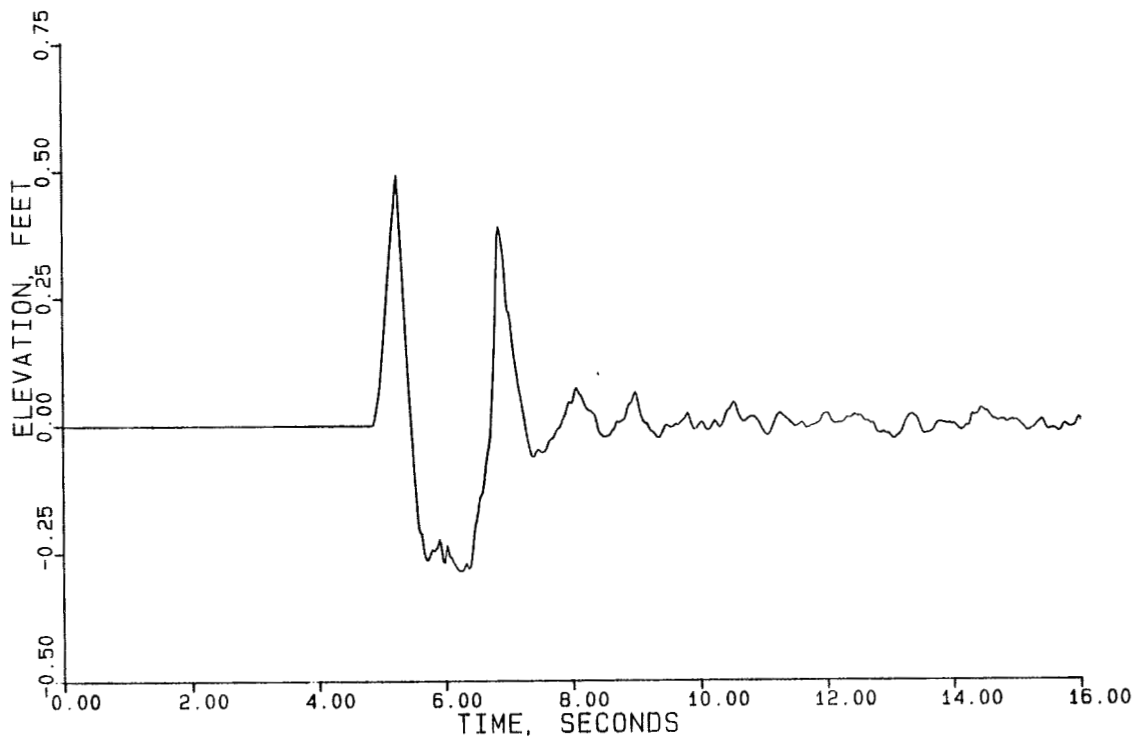
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 15, GAGE 8



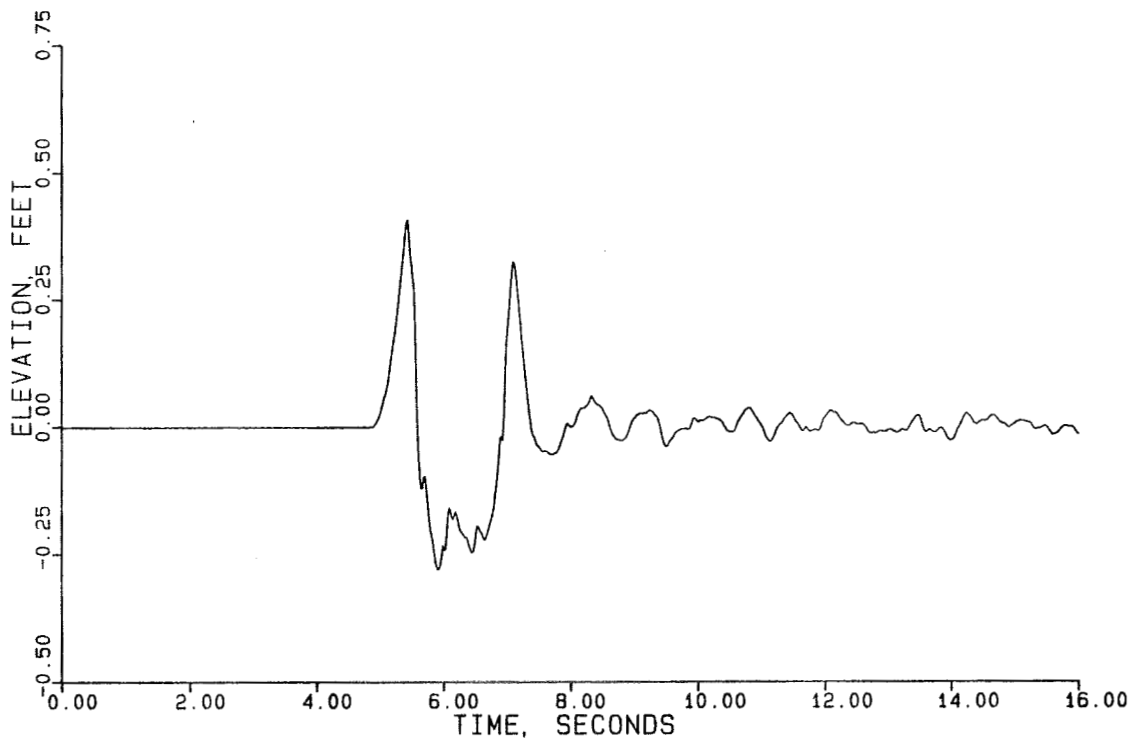
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 1



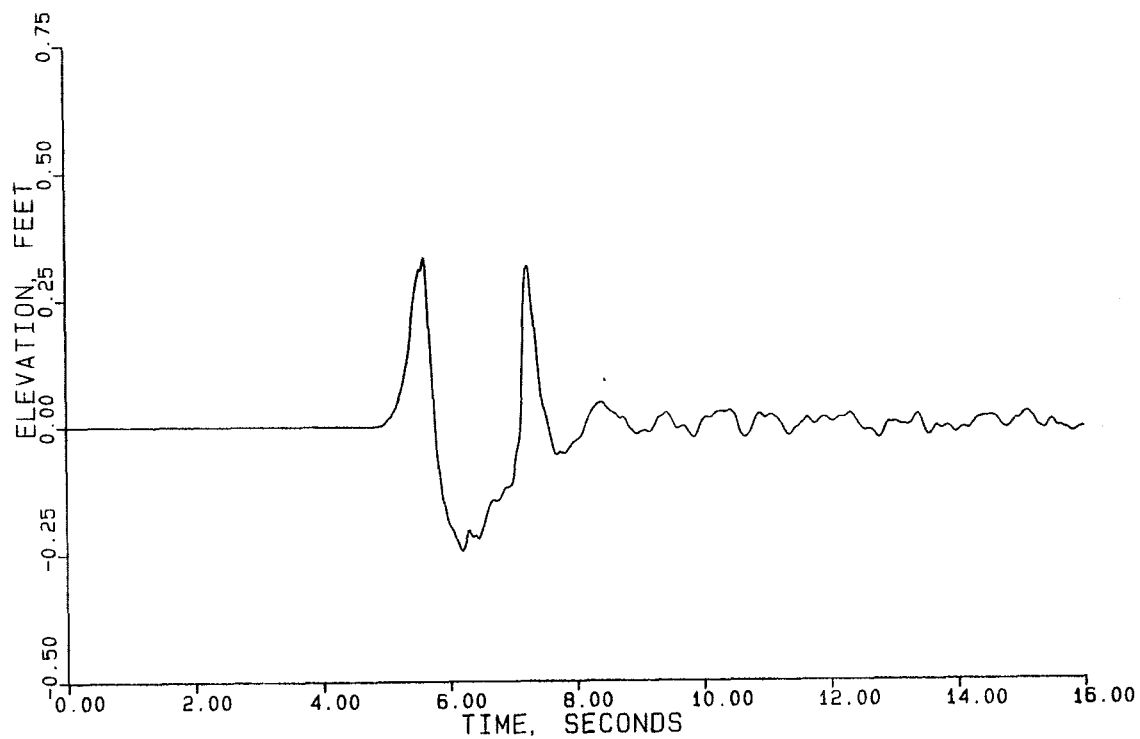
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 2



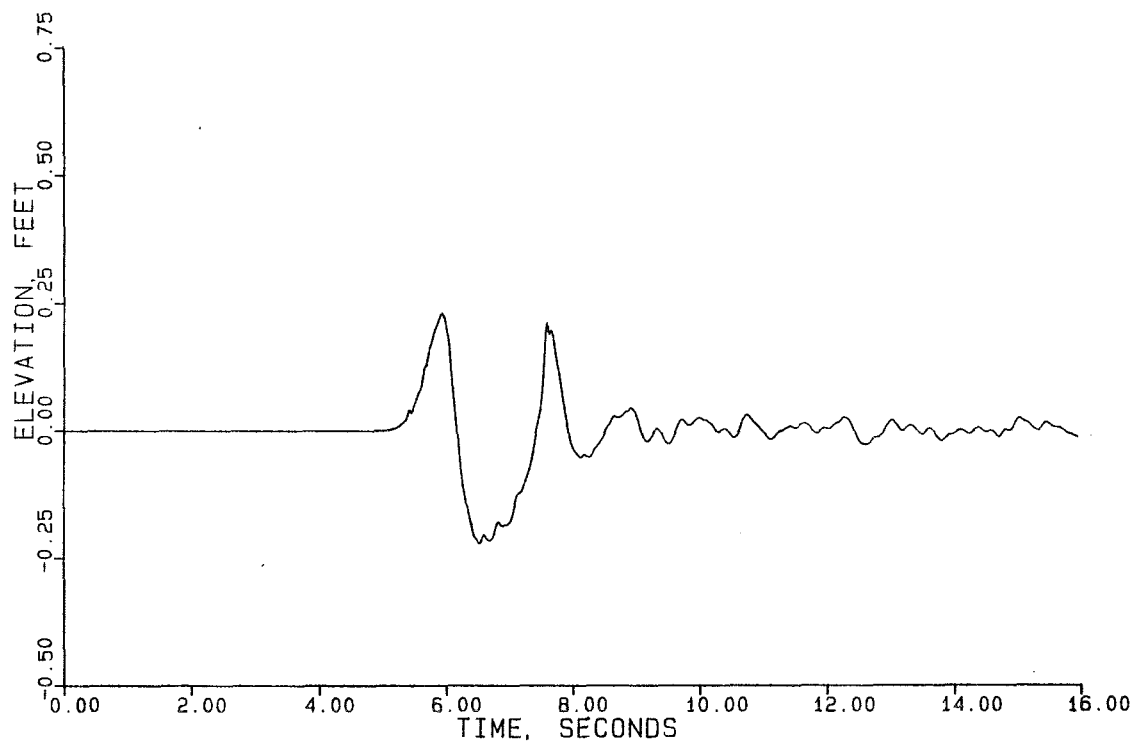
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 3



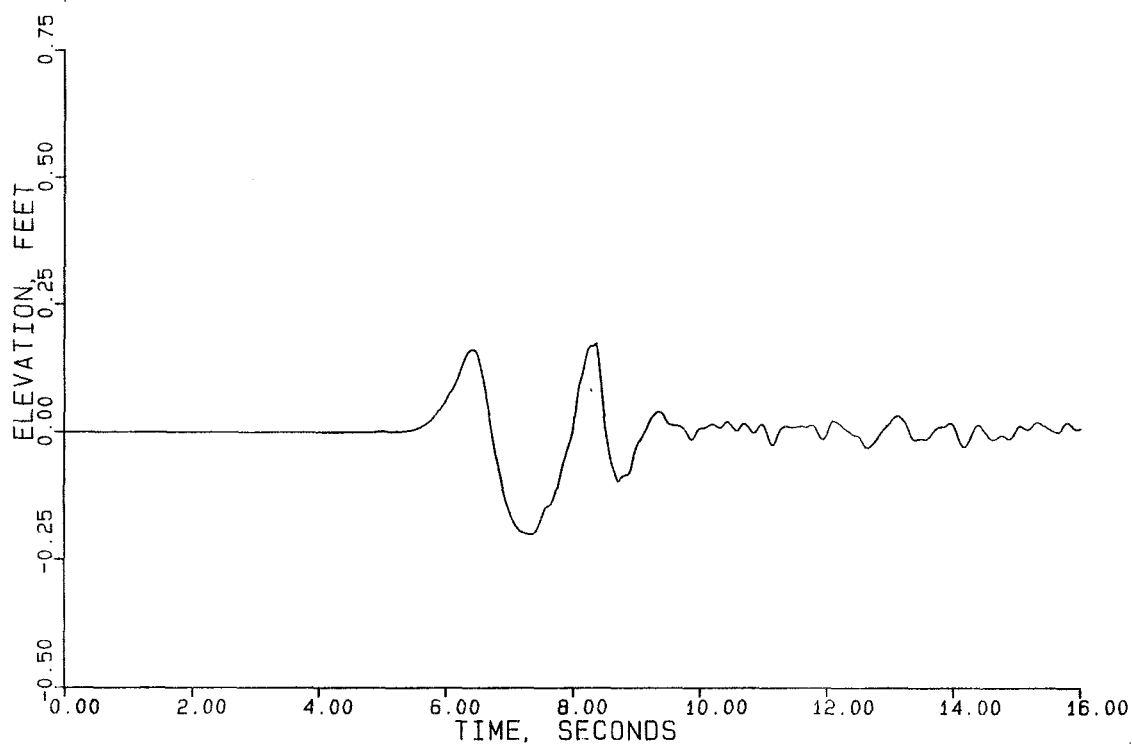
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 4



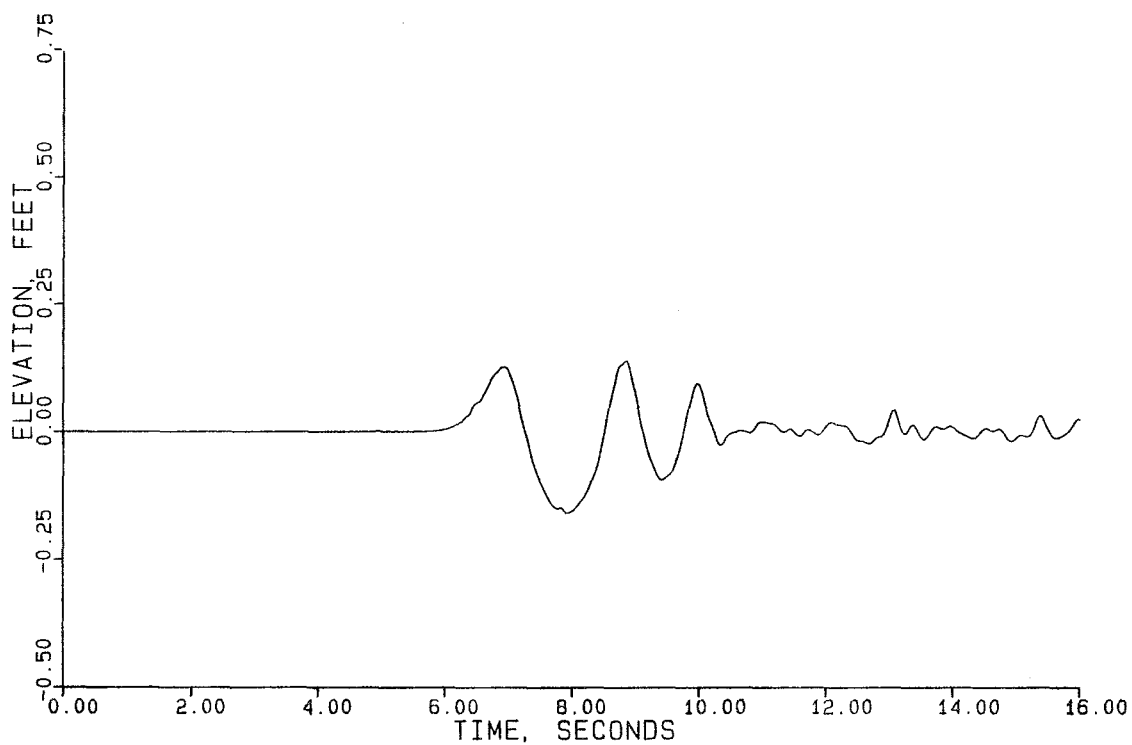
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 6

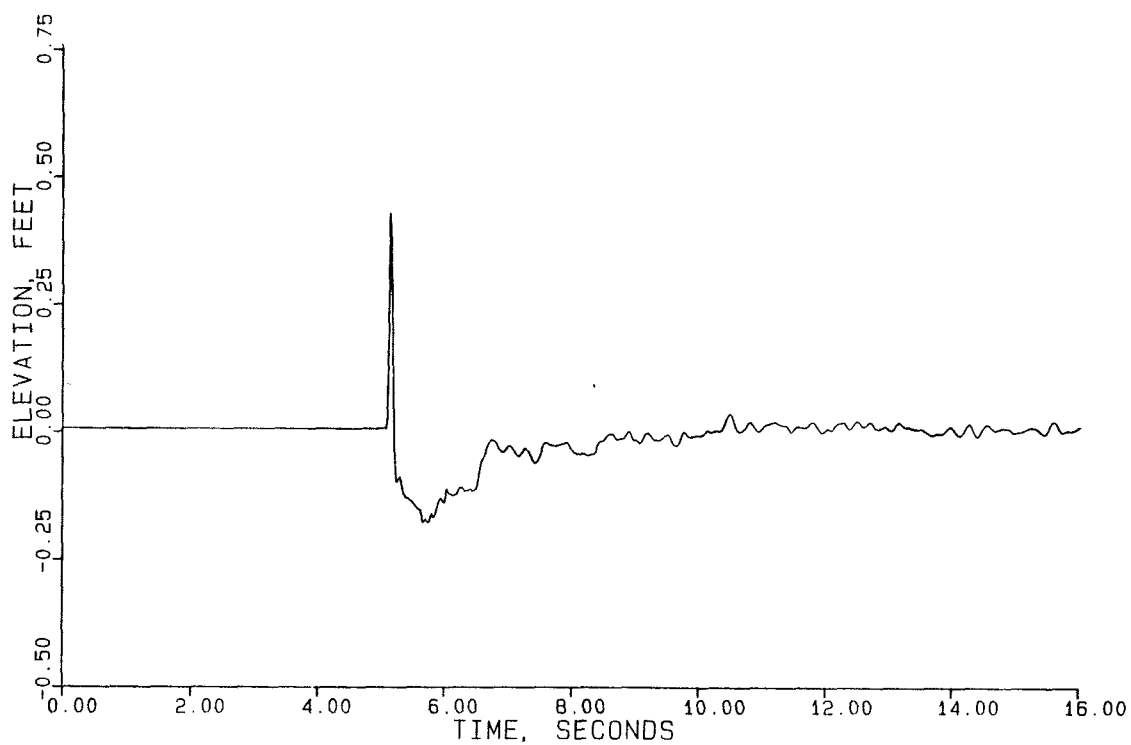


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 7

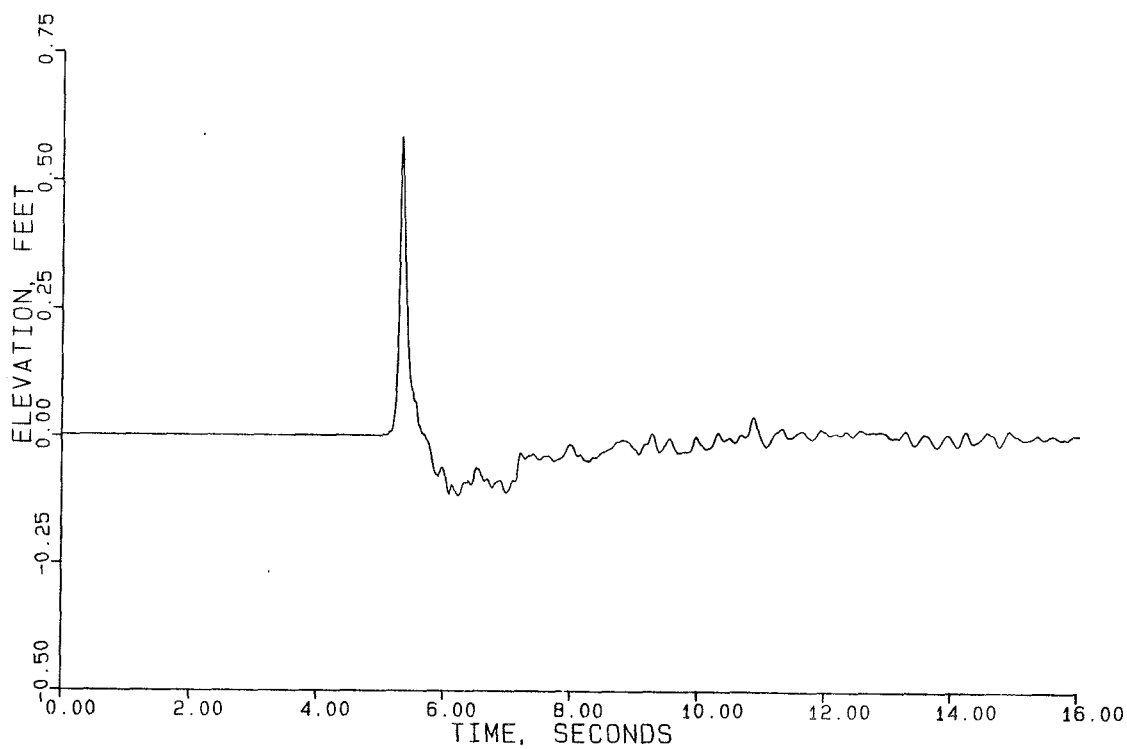


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 16, GAGE 8

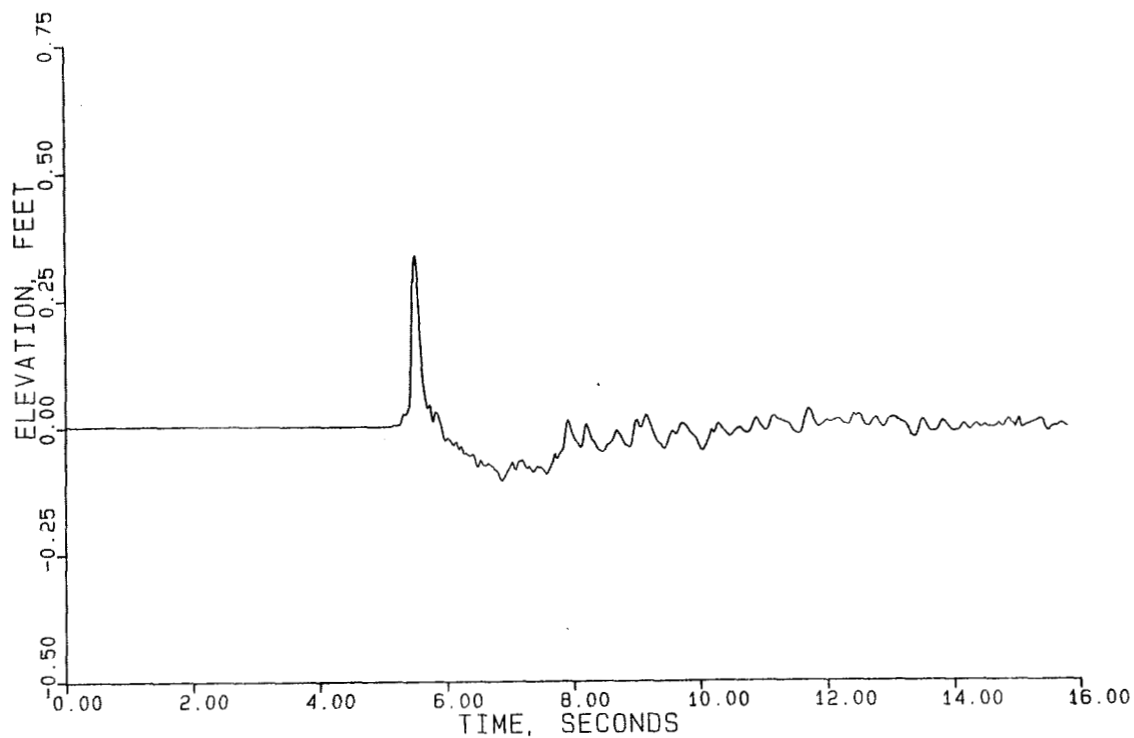




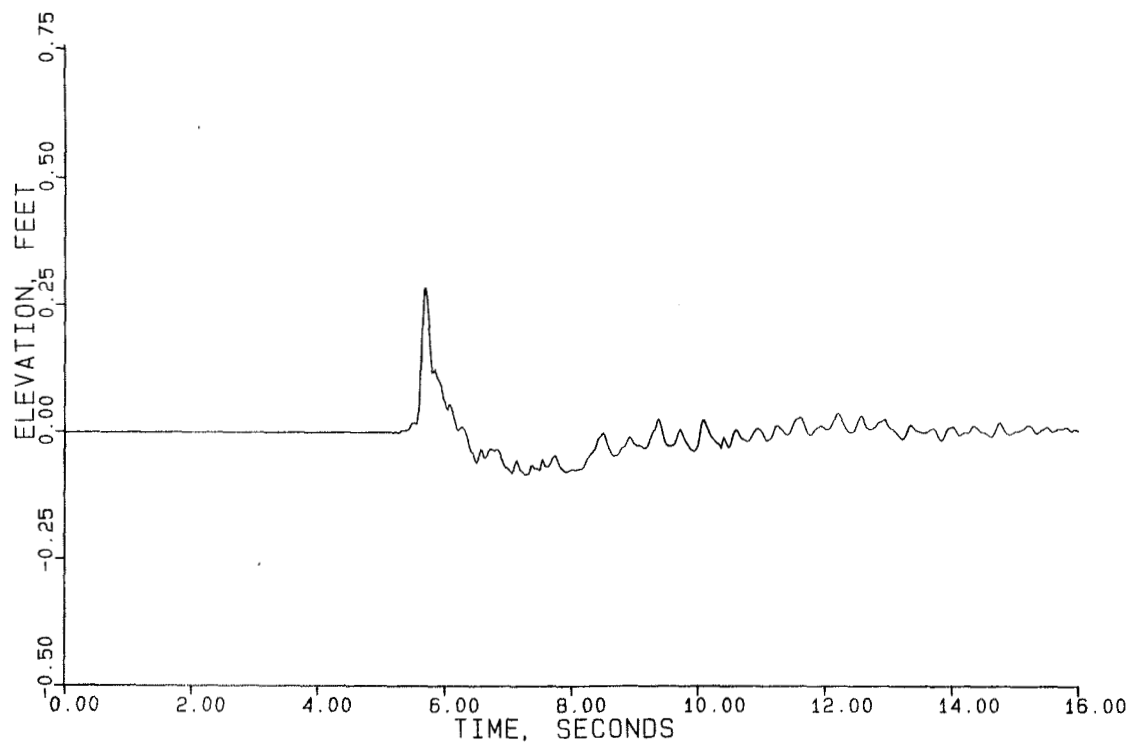
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 1



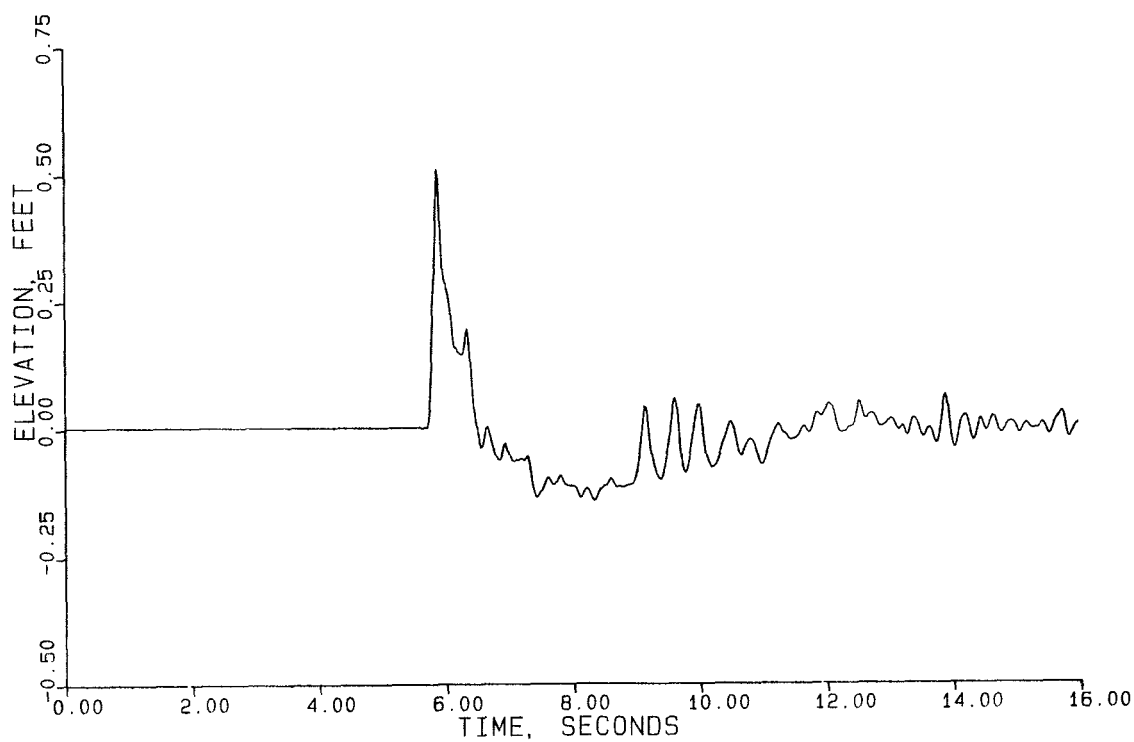
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 2



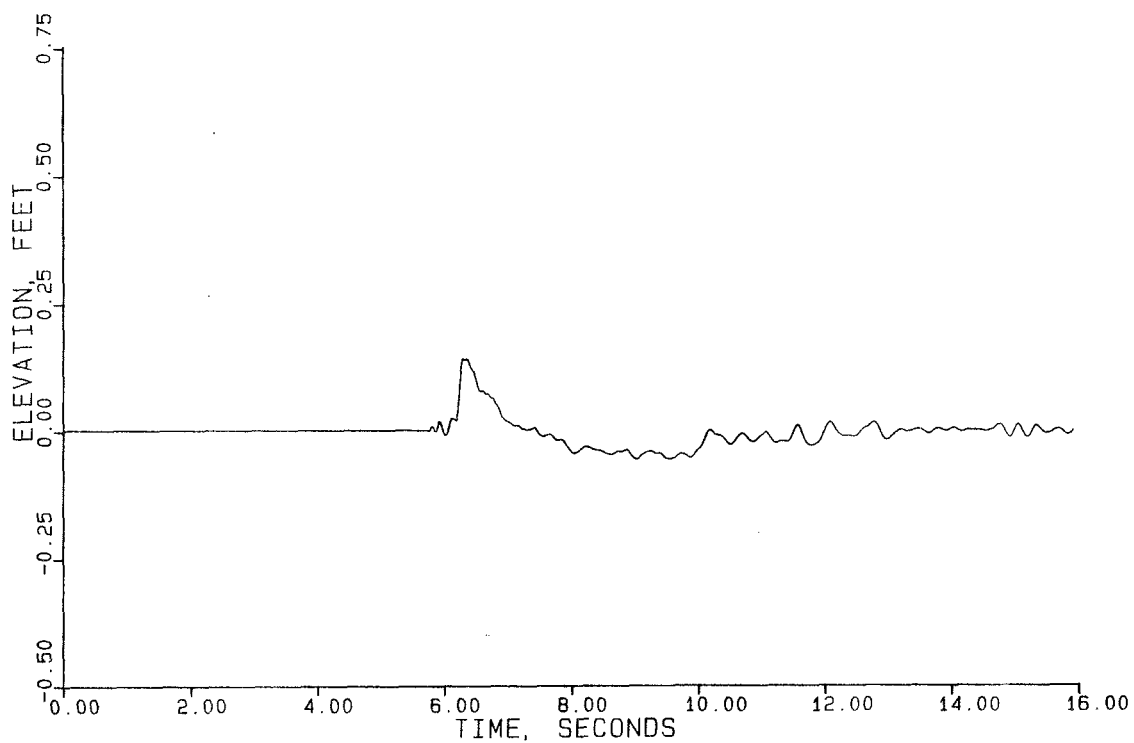
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 3



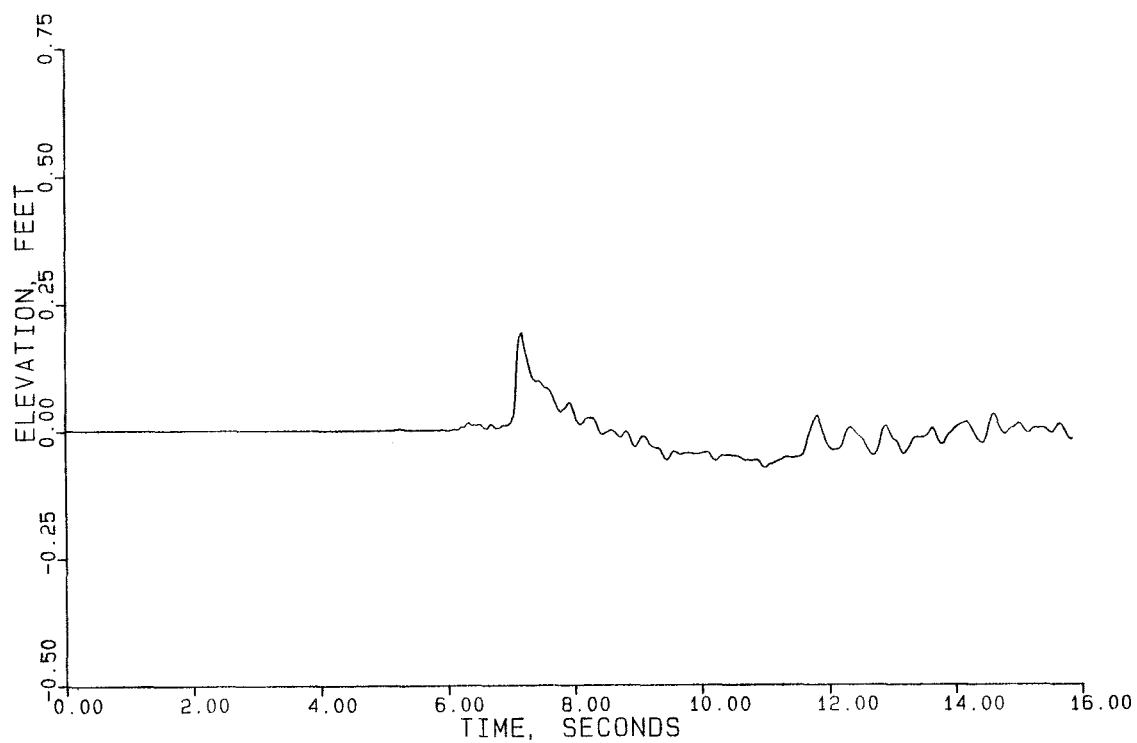
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 4



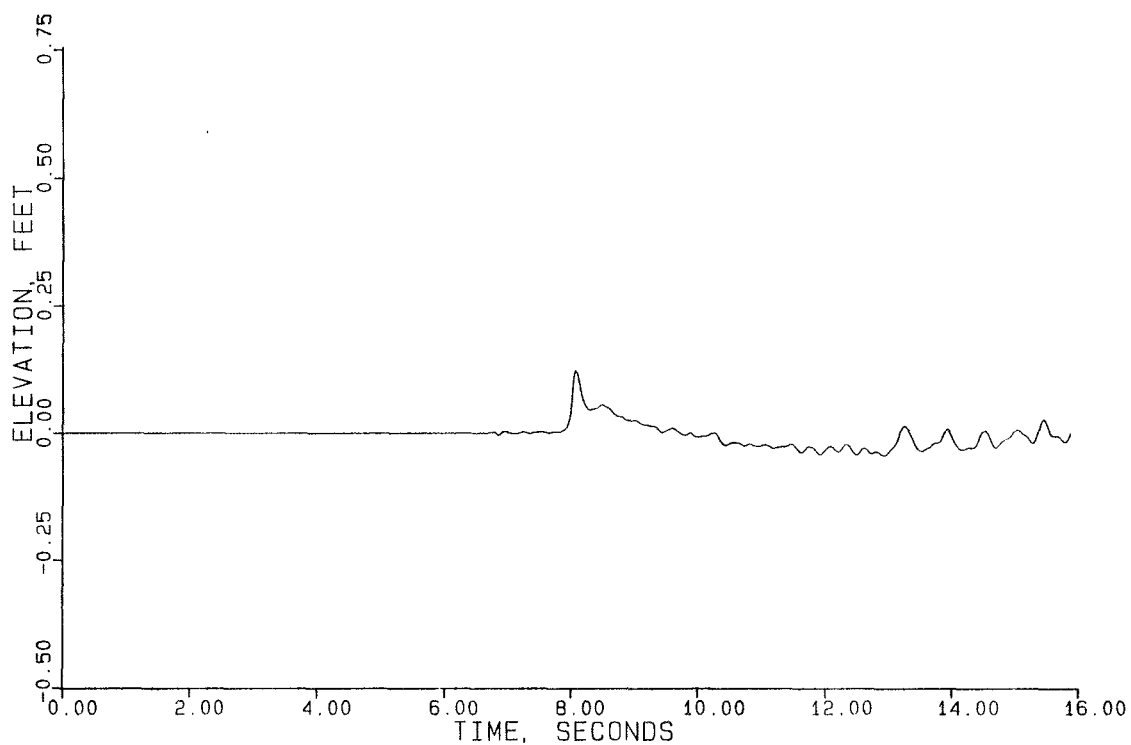
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 5



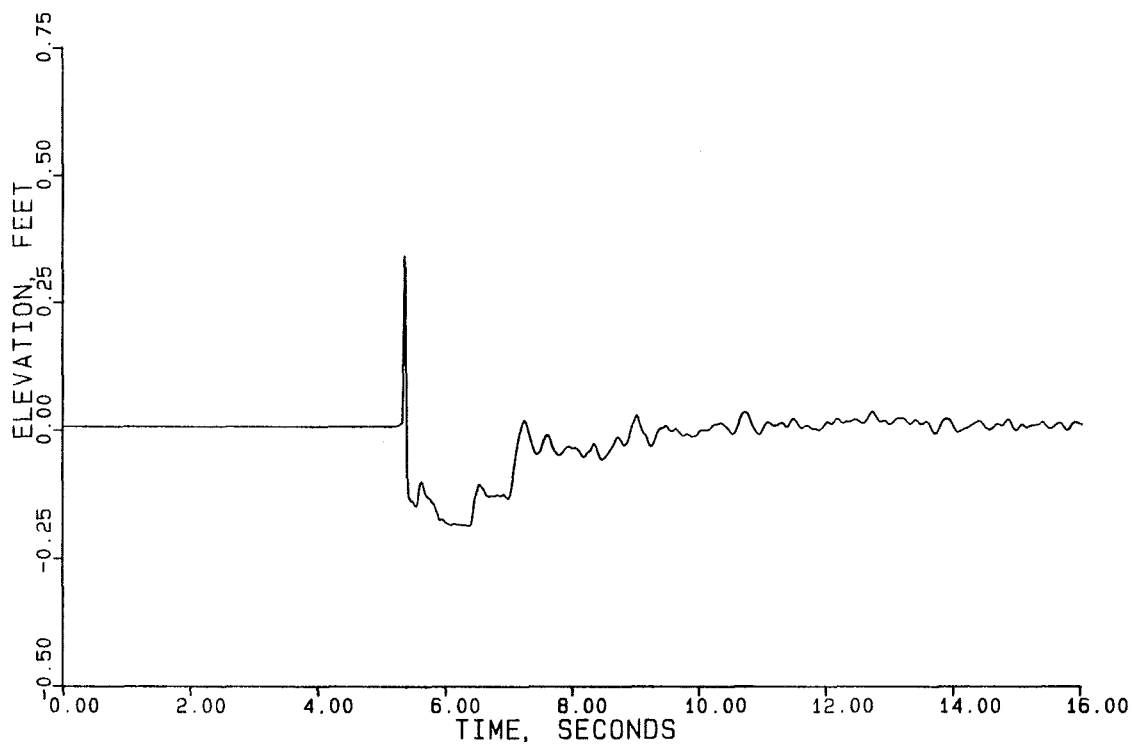
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 6



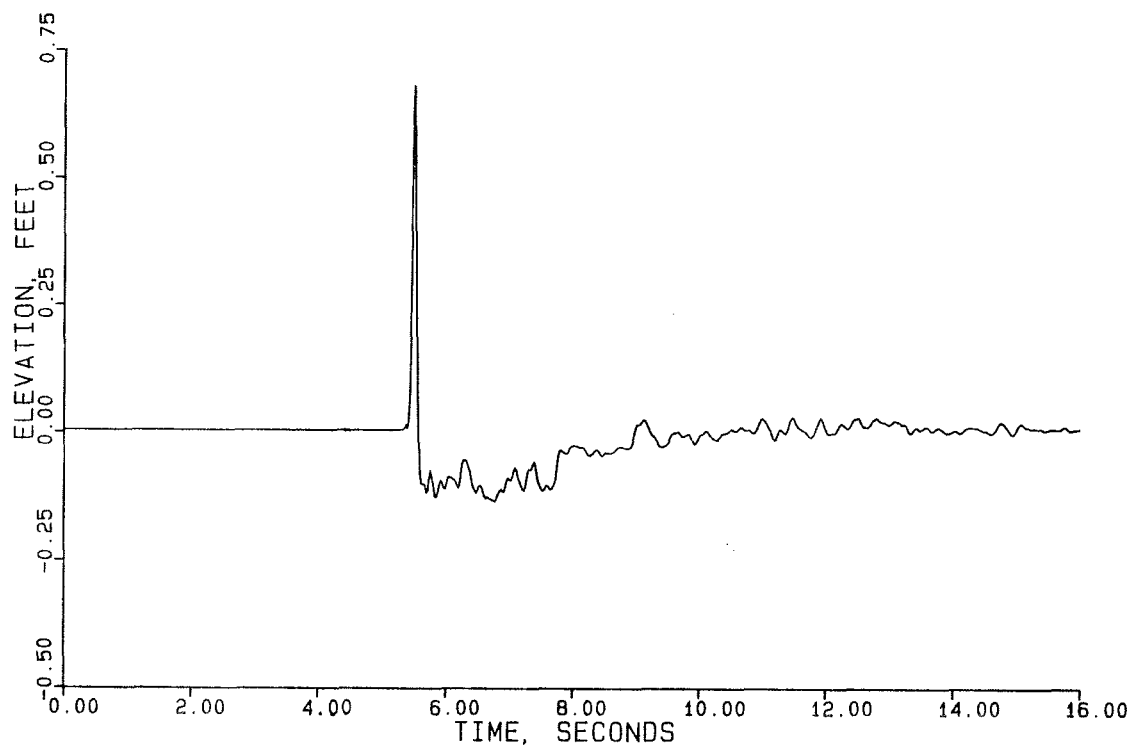
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 7



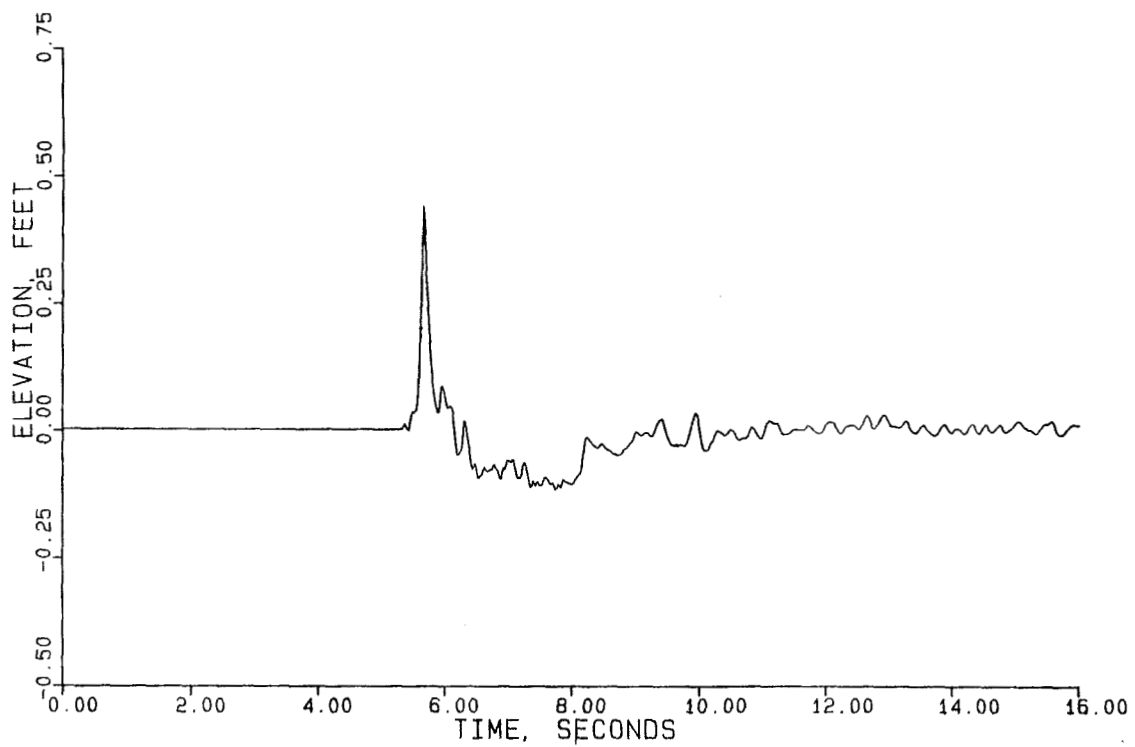
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 17, GAGE 8



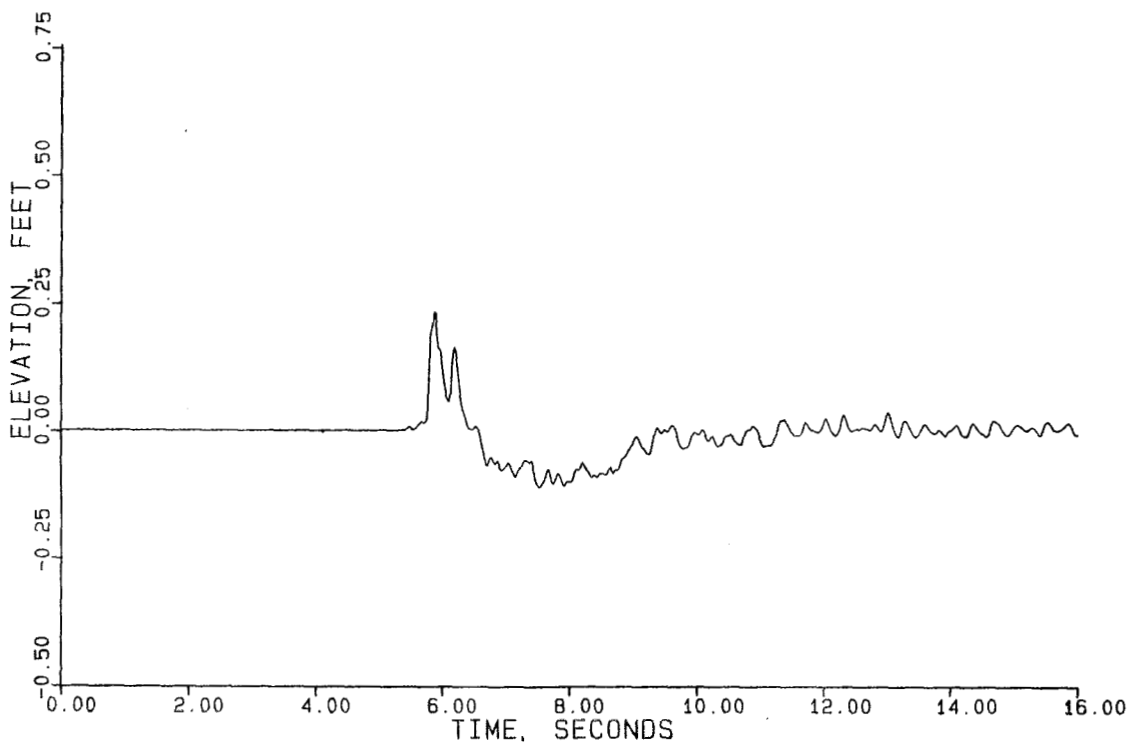
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 1



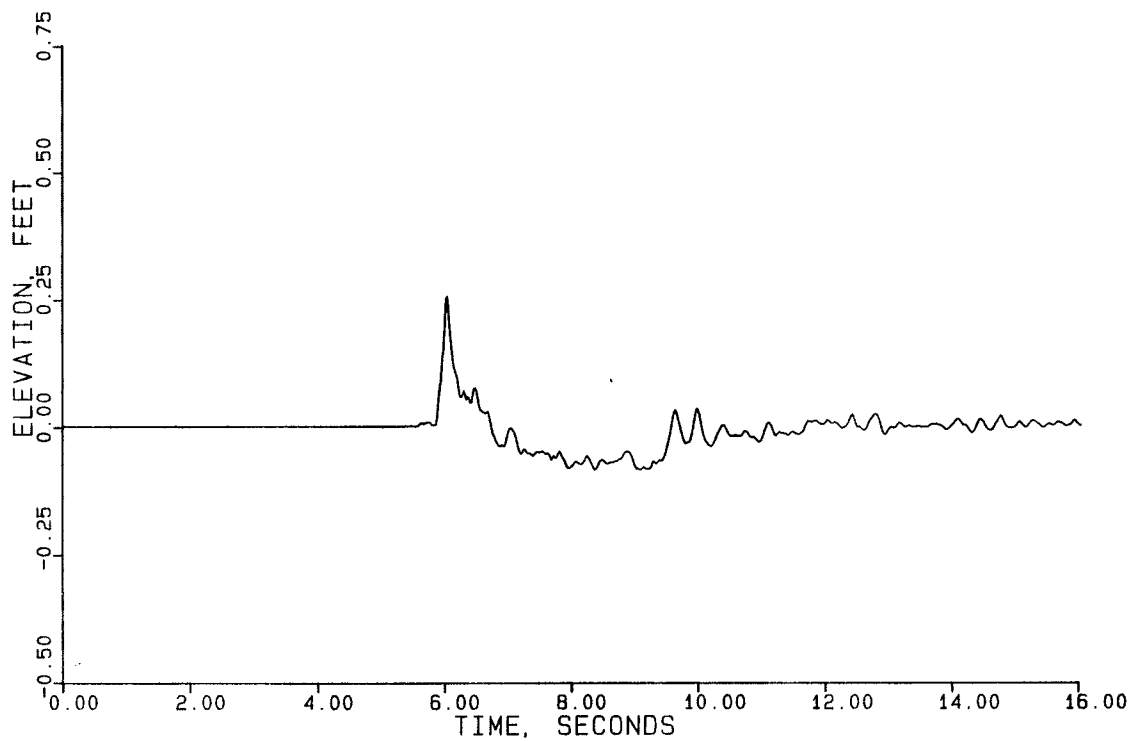
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 2



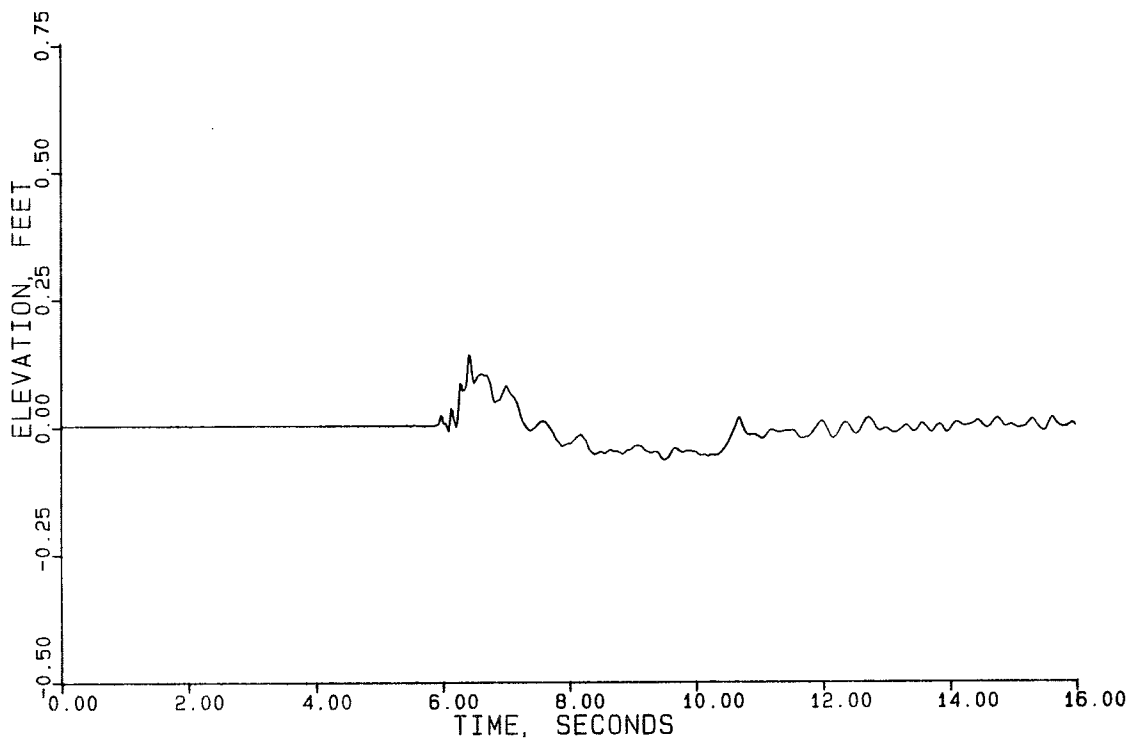
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 3



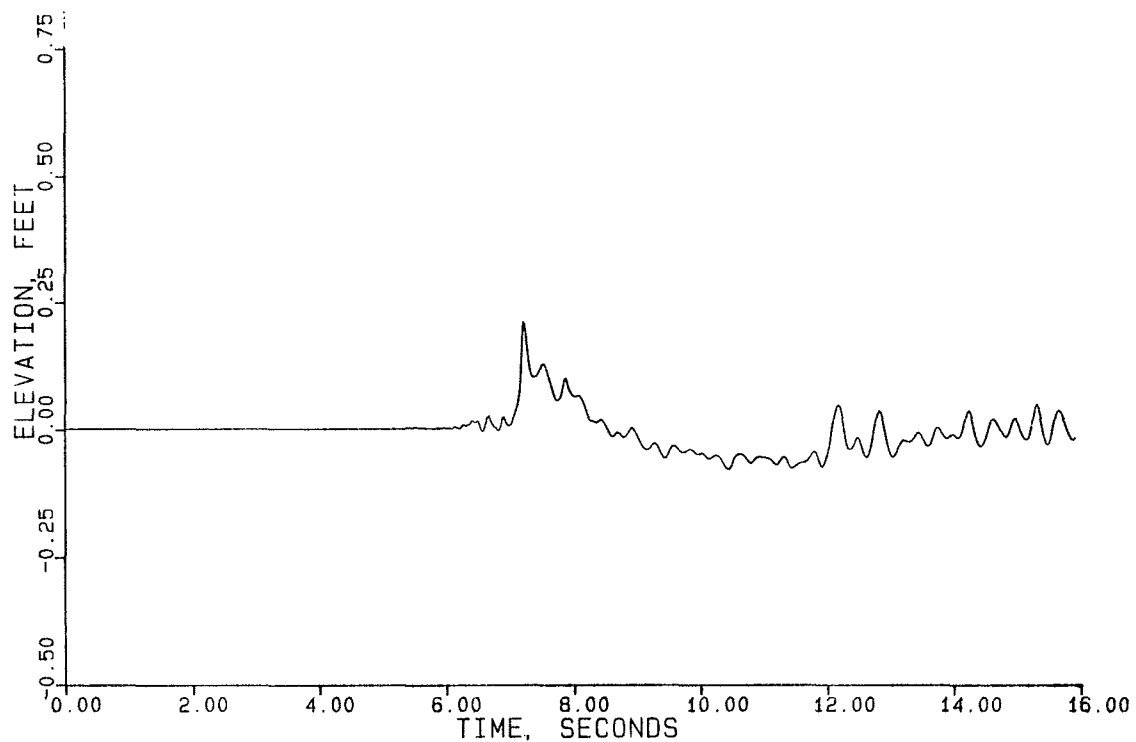
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 4



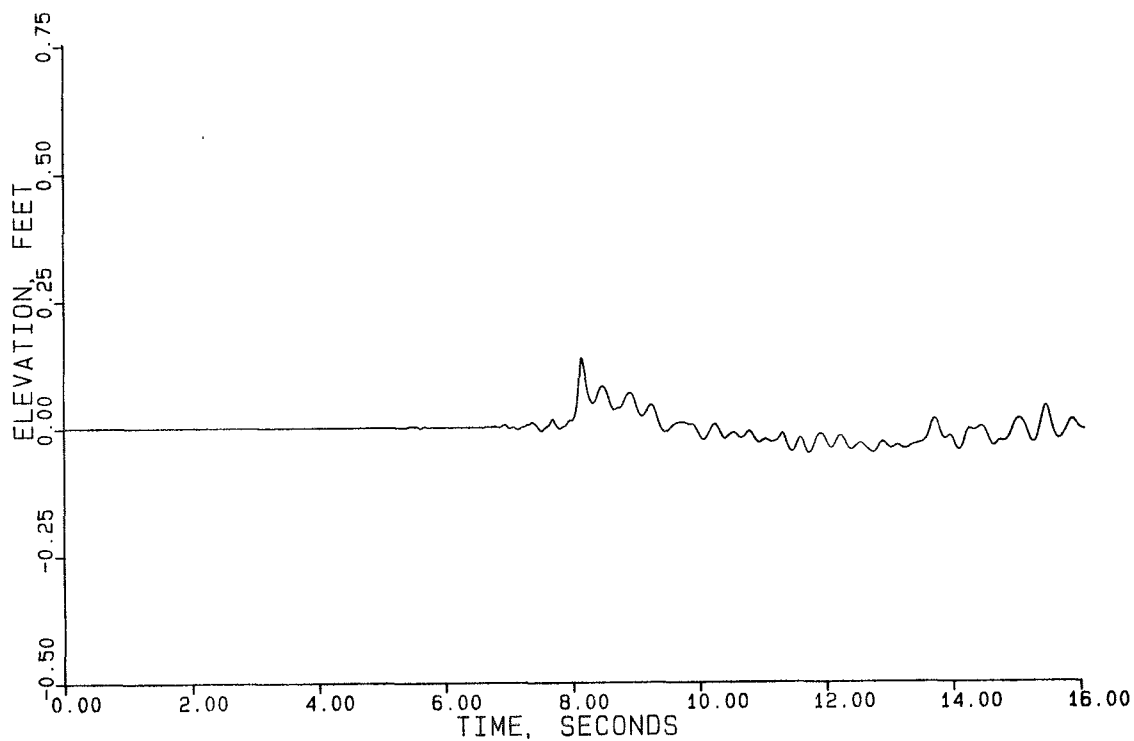
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 6

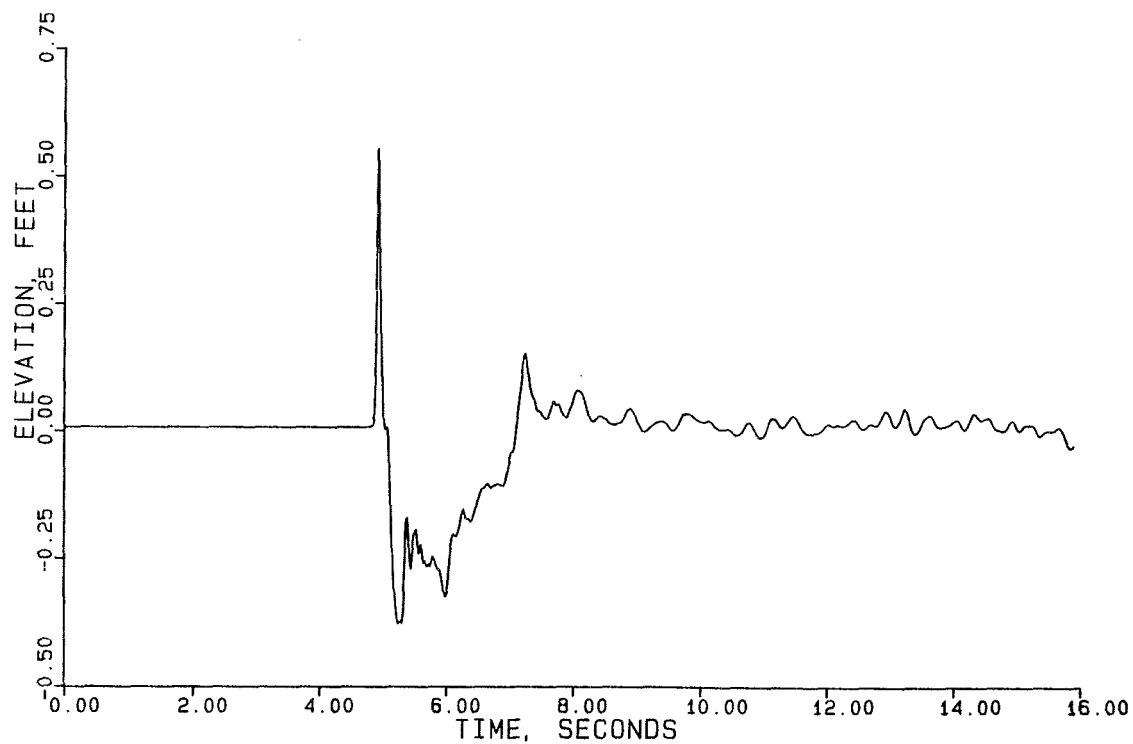


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 7

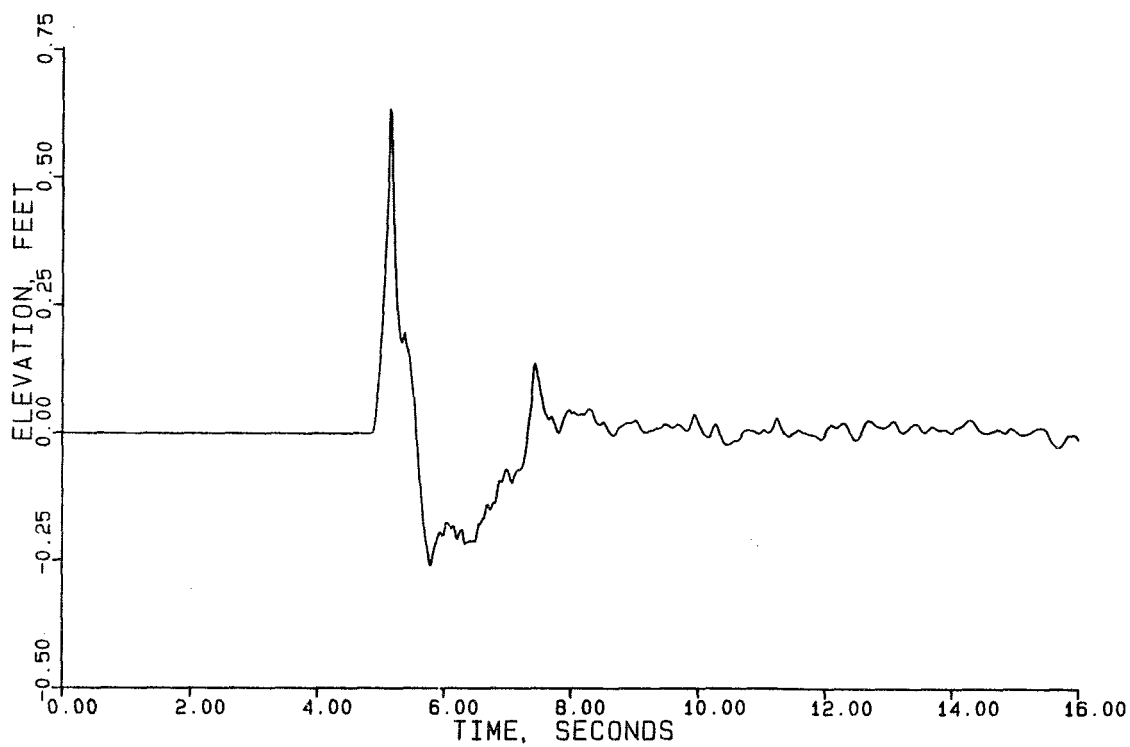


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 18, GAGE 8

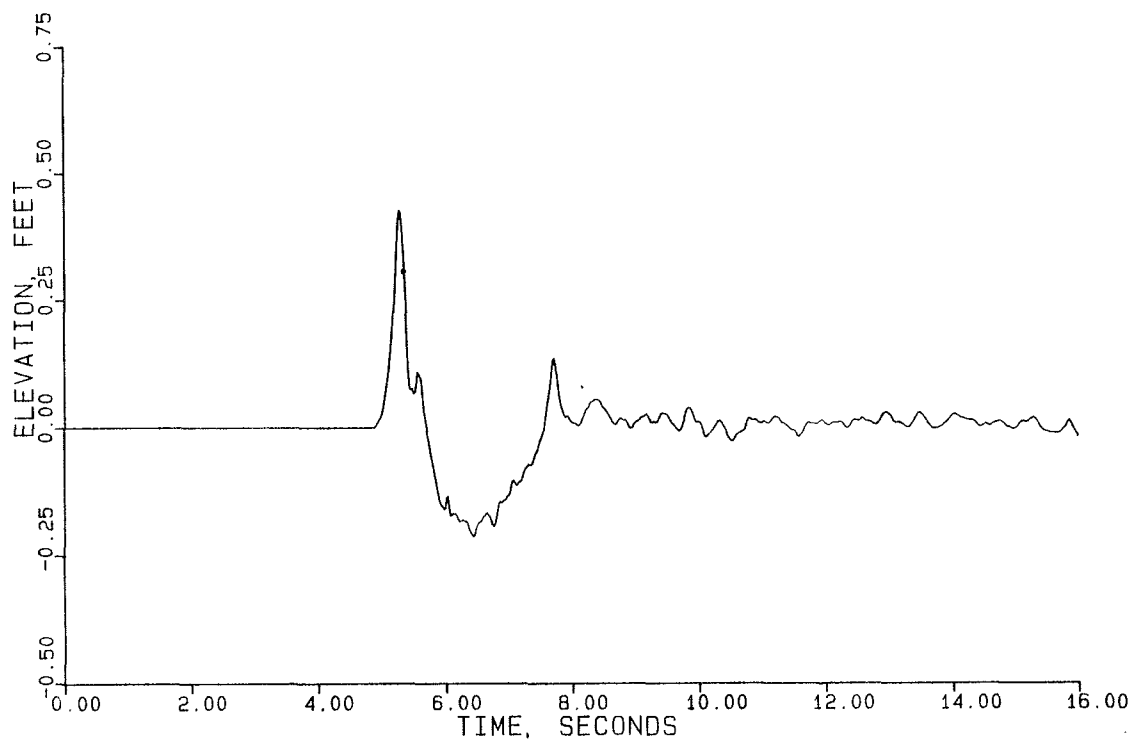




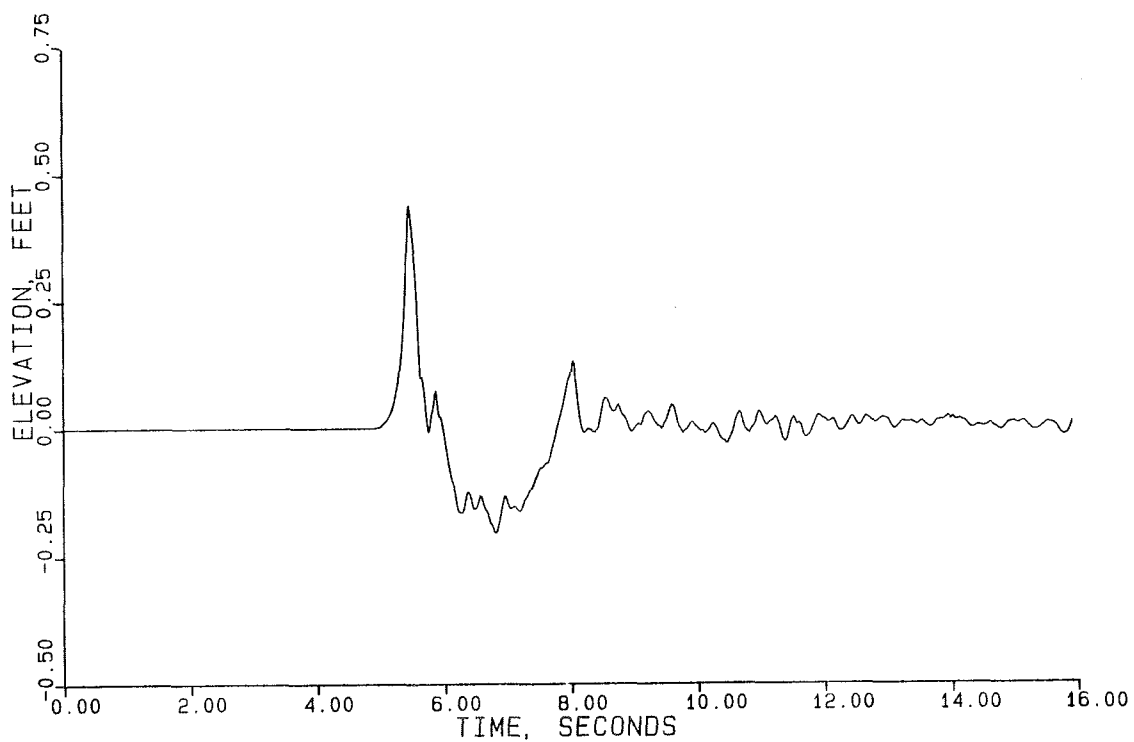
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 1



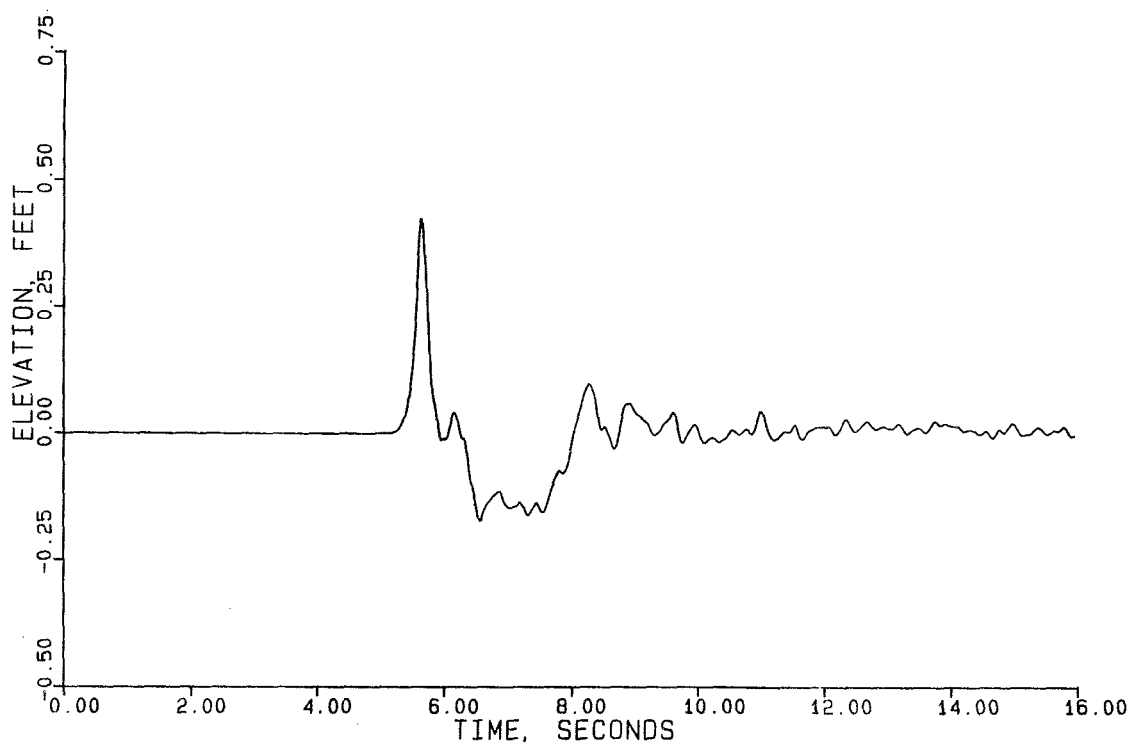
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 2



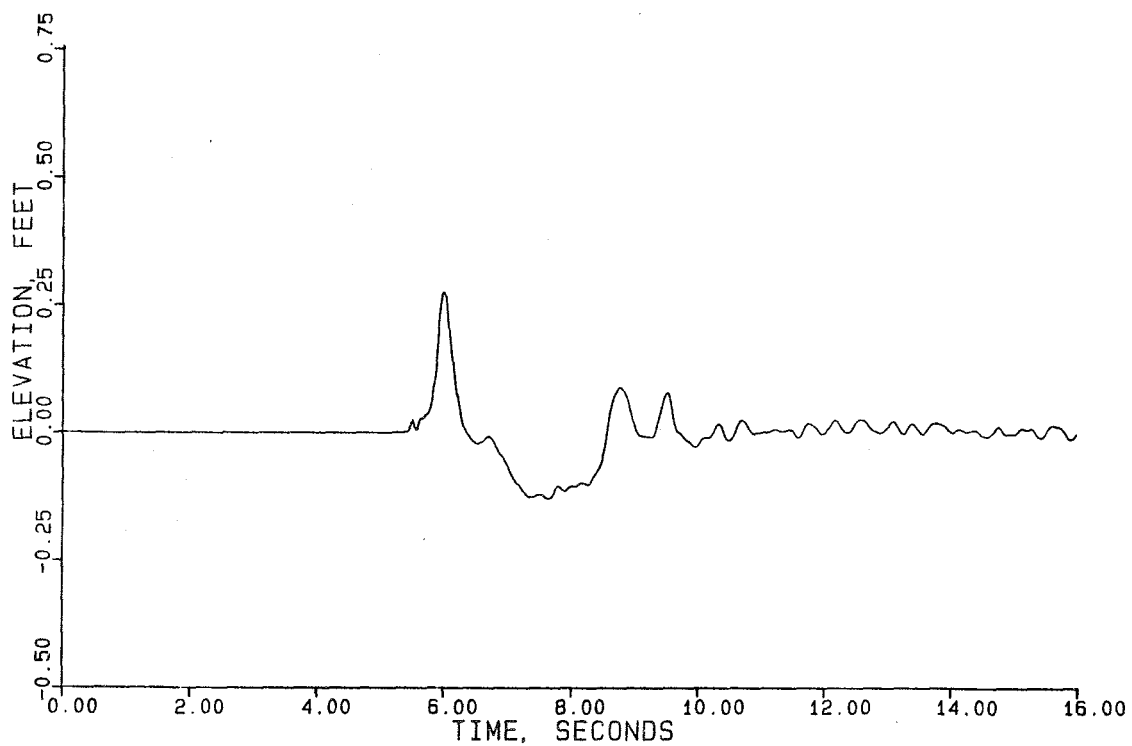
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 3



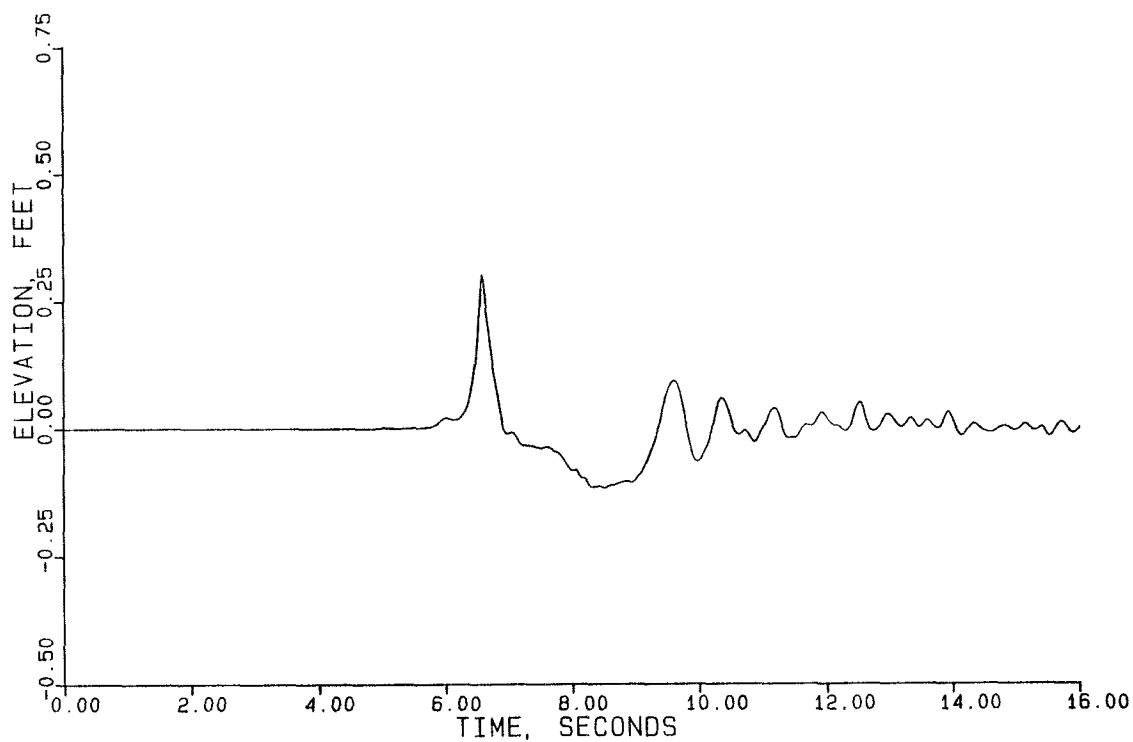
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 4



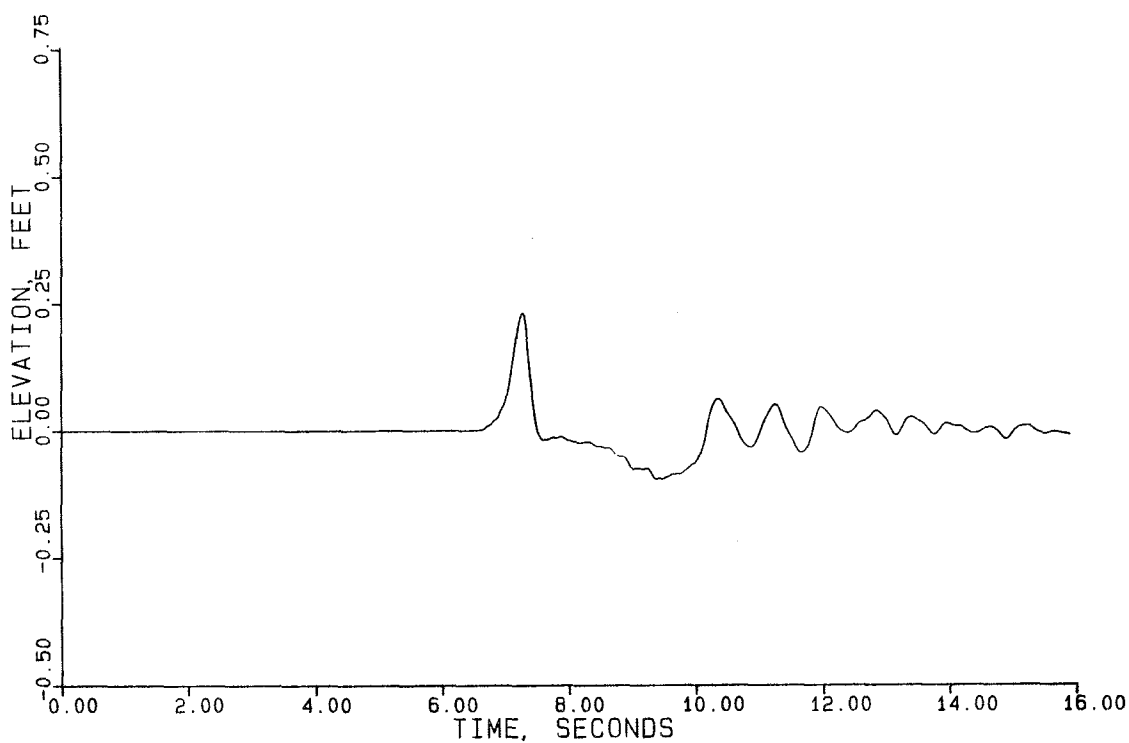
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 5



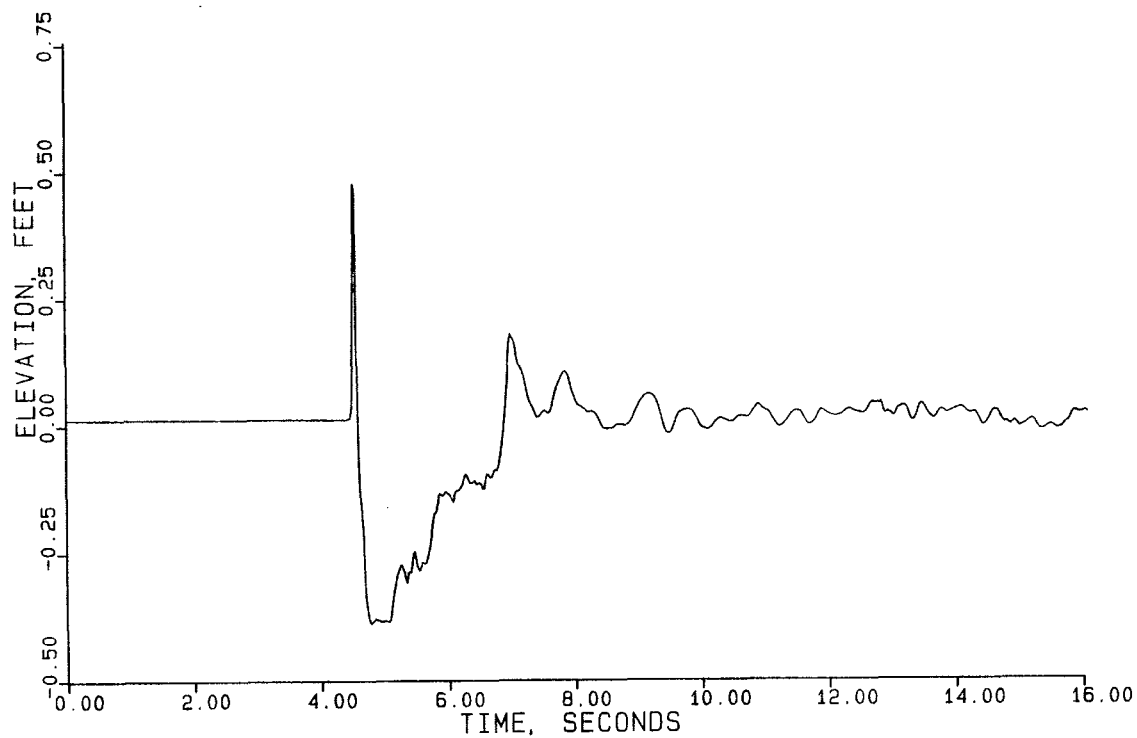
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 6



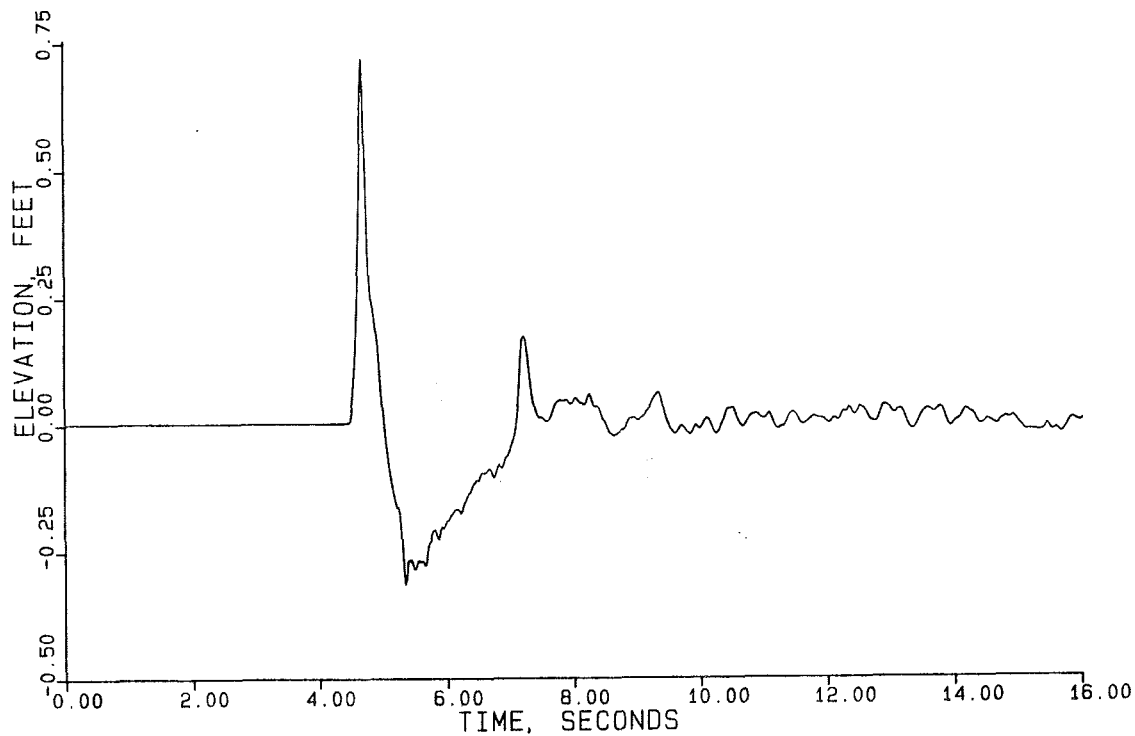
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 7



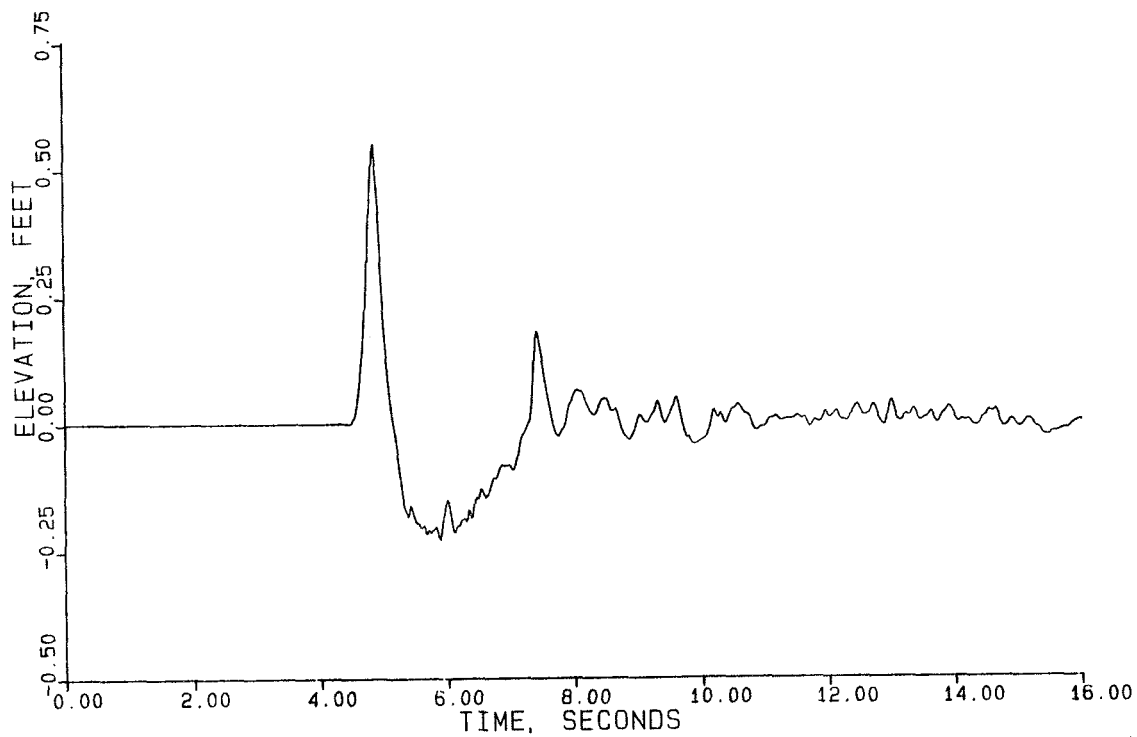
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 19, GAGE 8



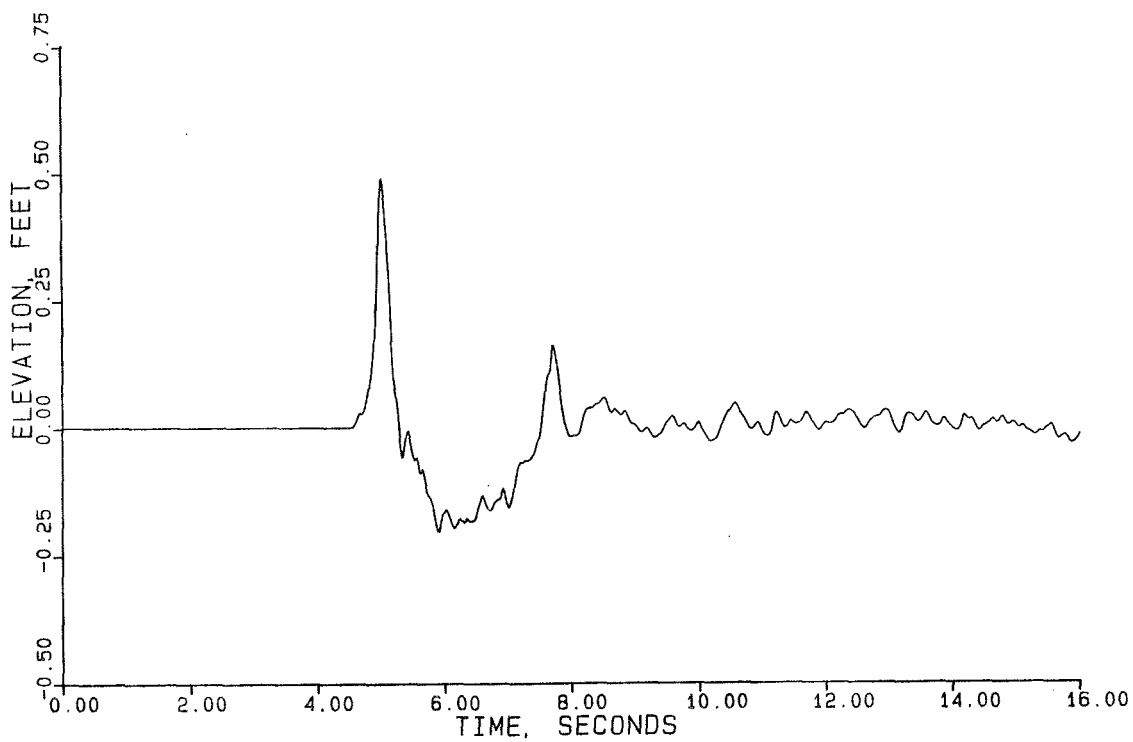
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 1



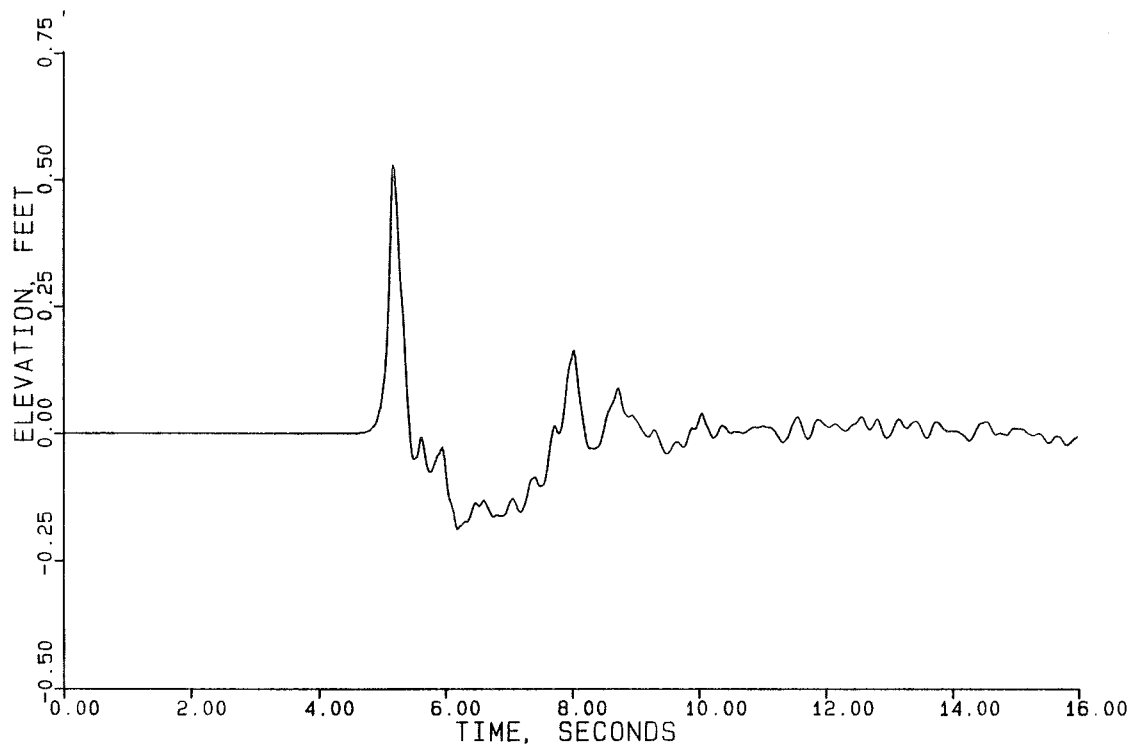
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 2



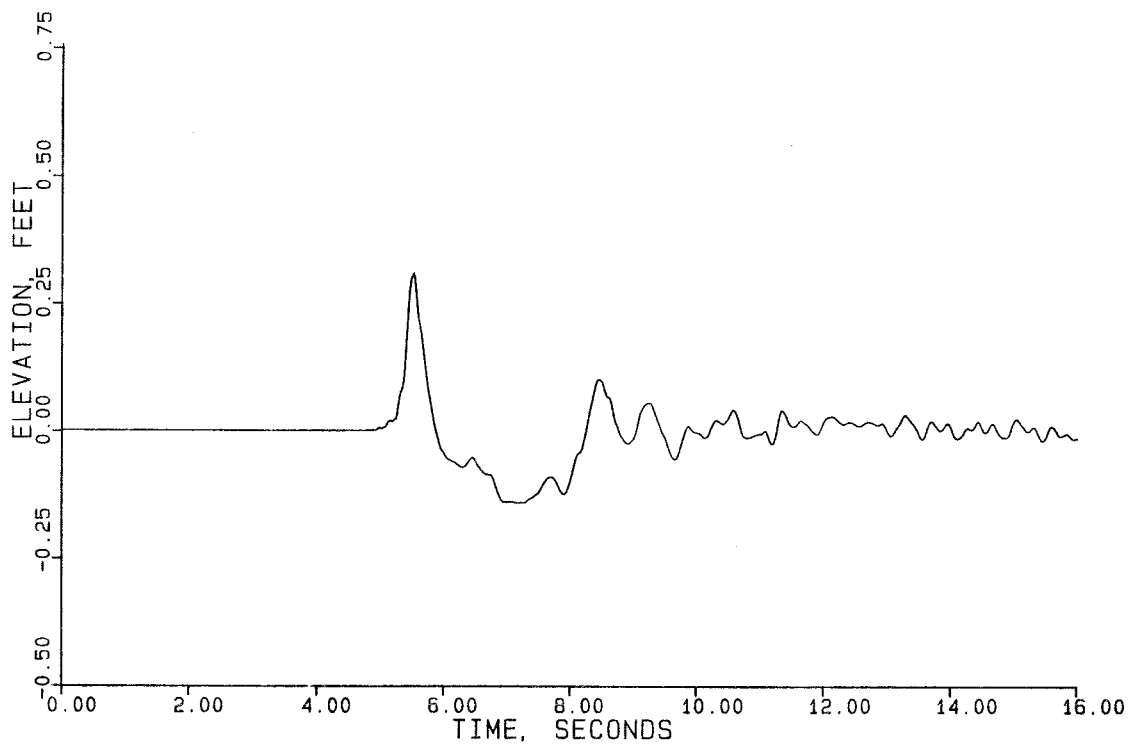
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 3



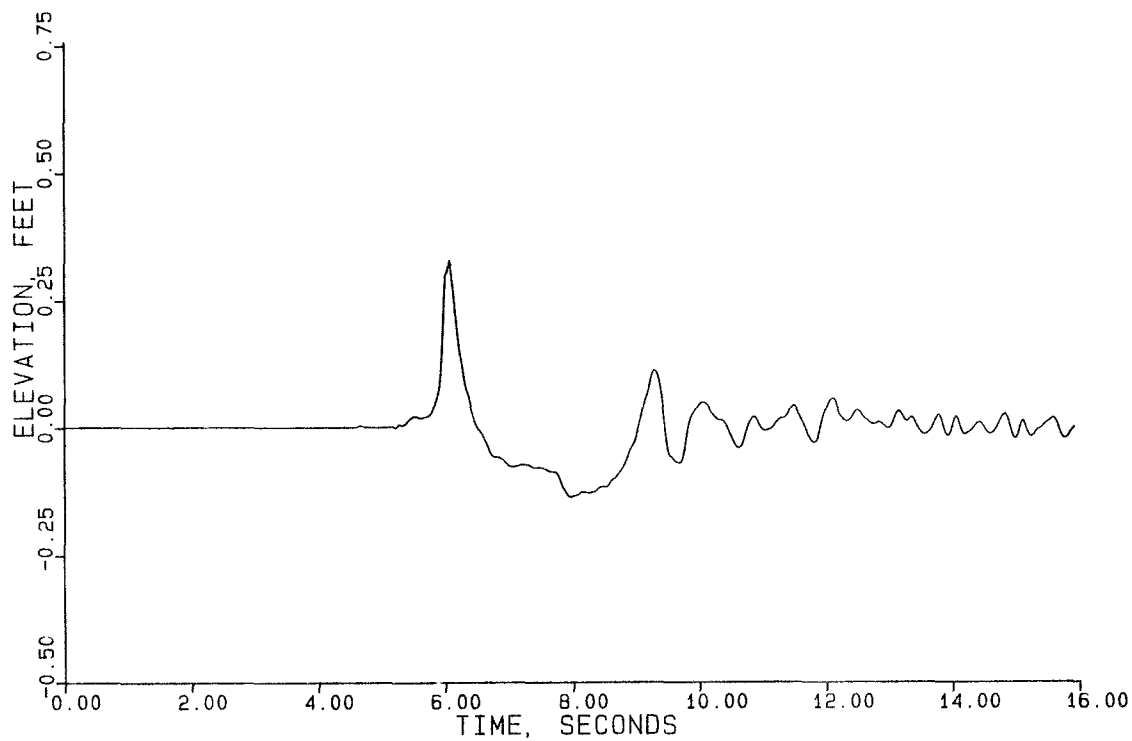
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 4



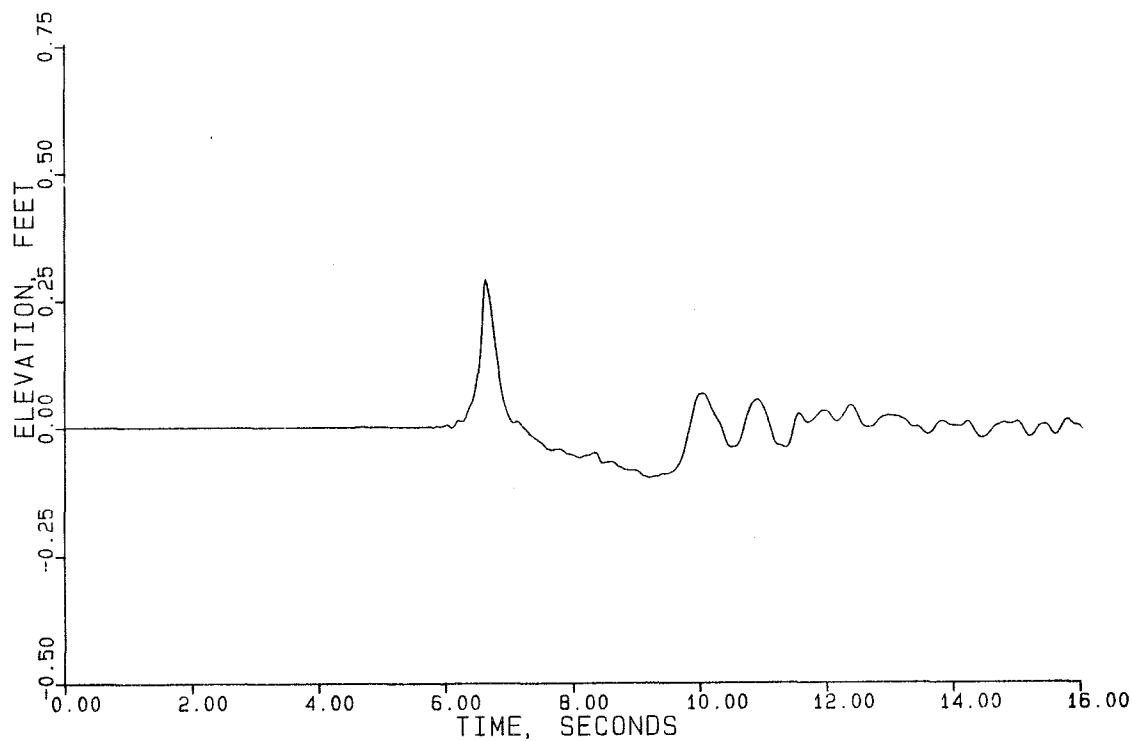
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 6

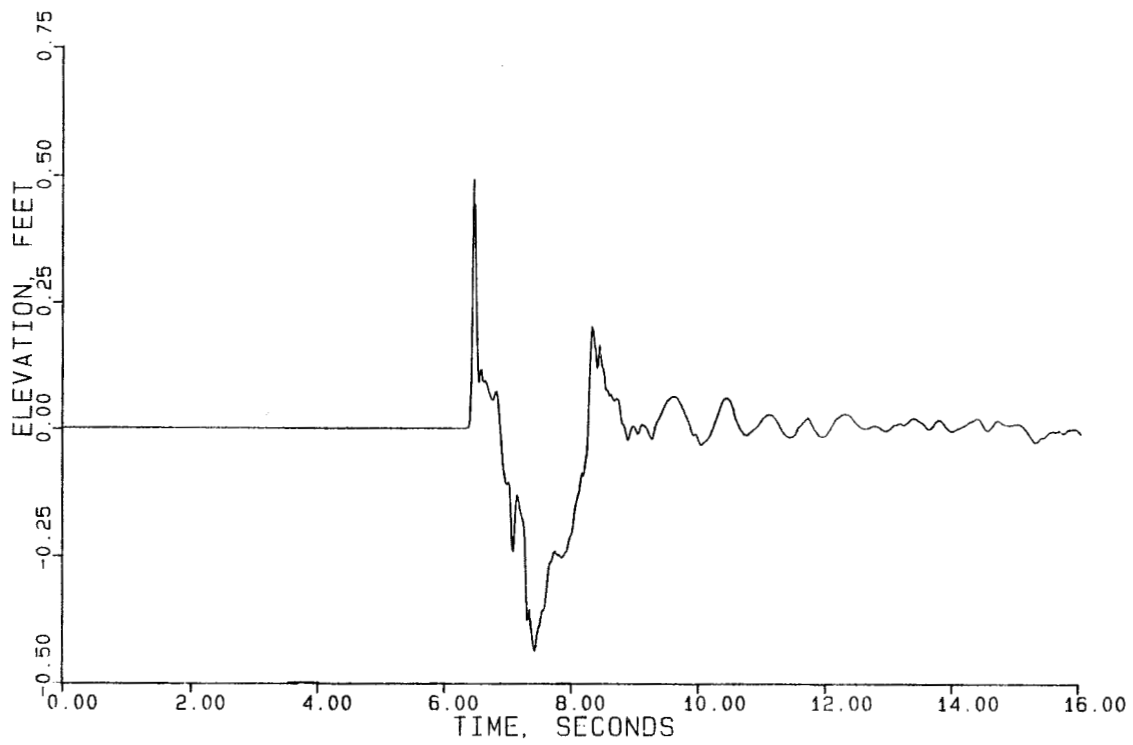


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 7

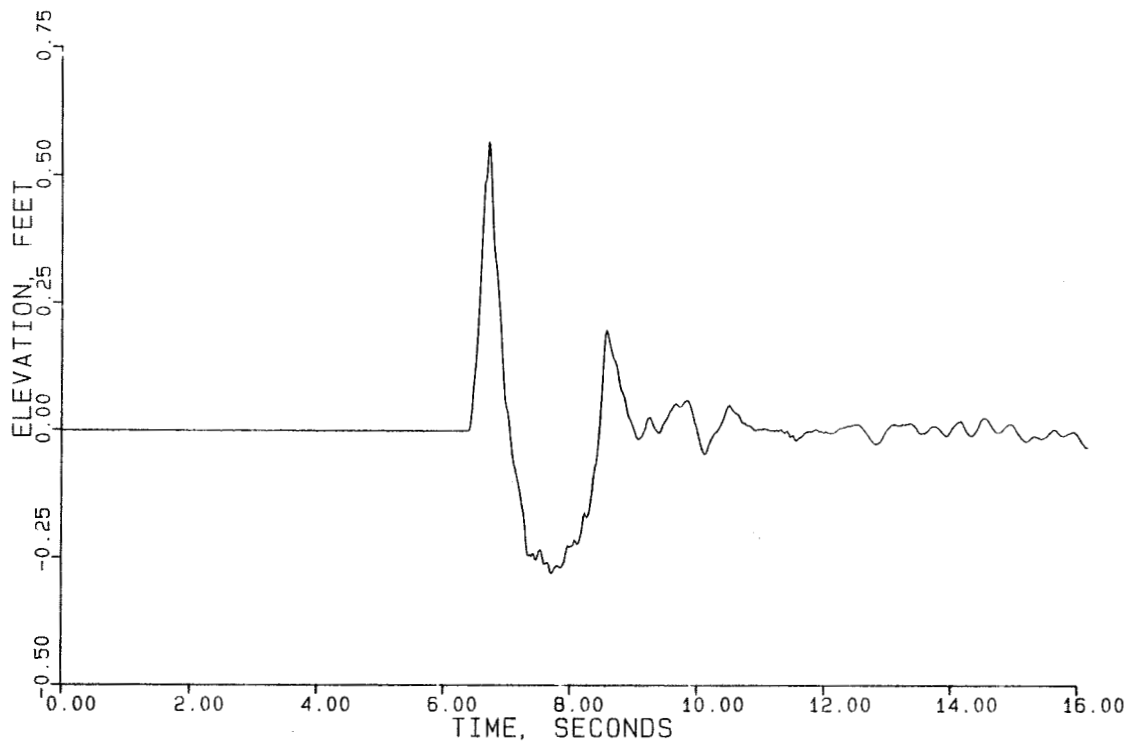


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 20, GAGE 8

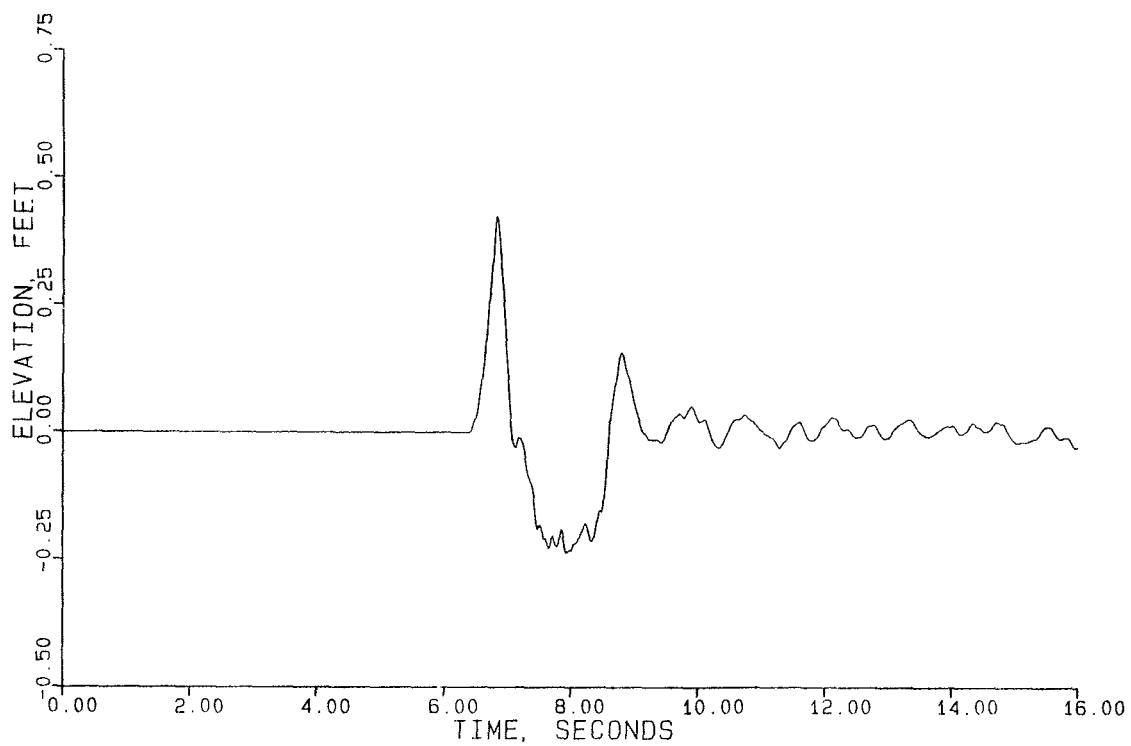




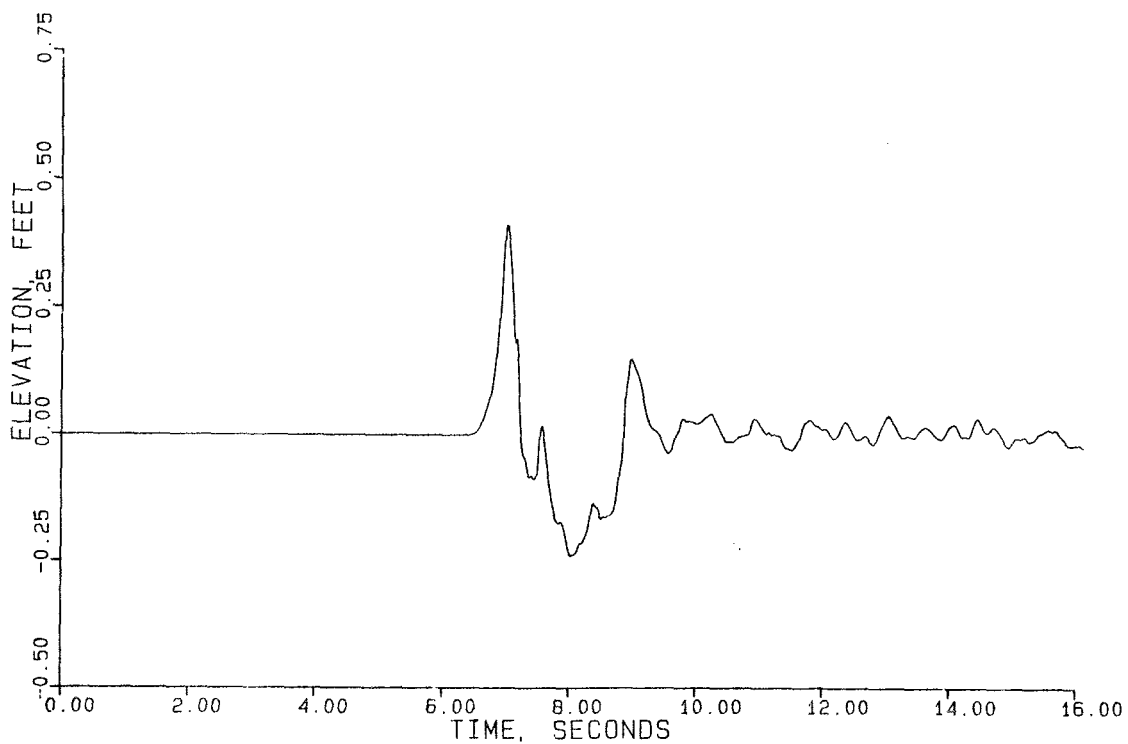
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 1



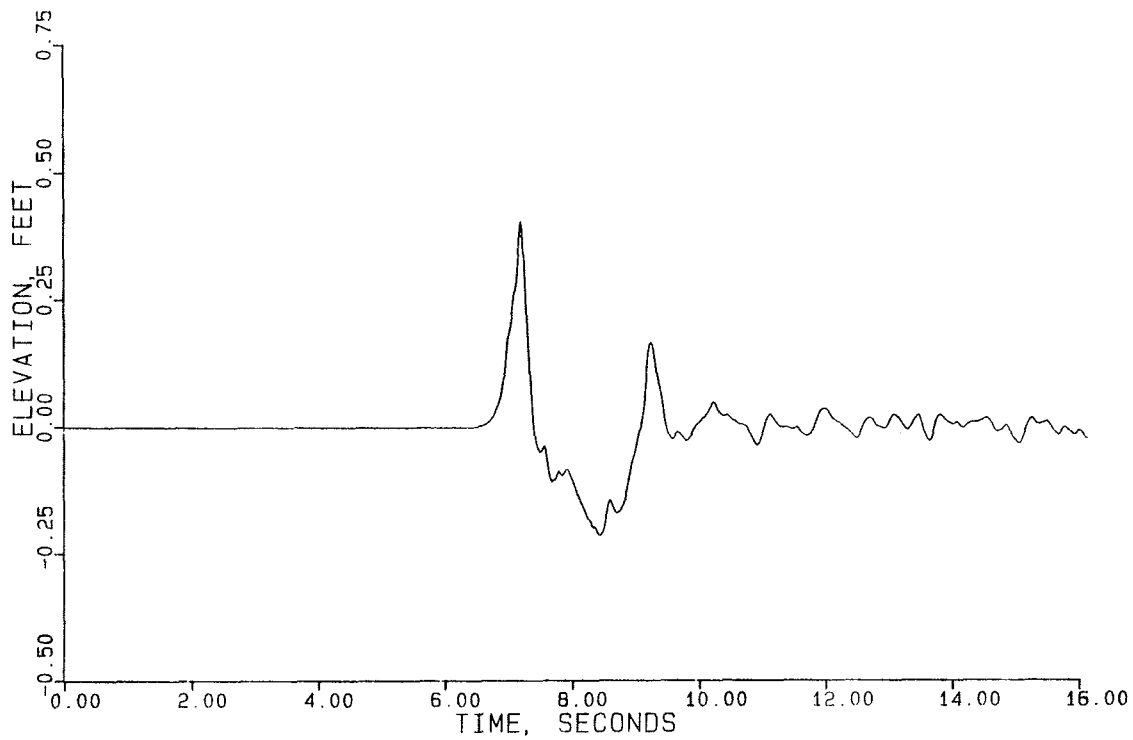
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 2



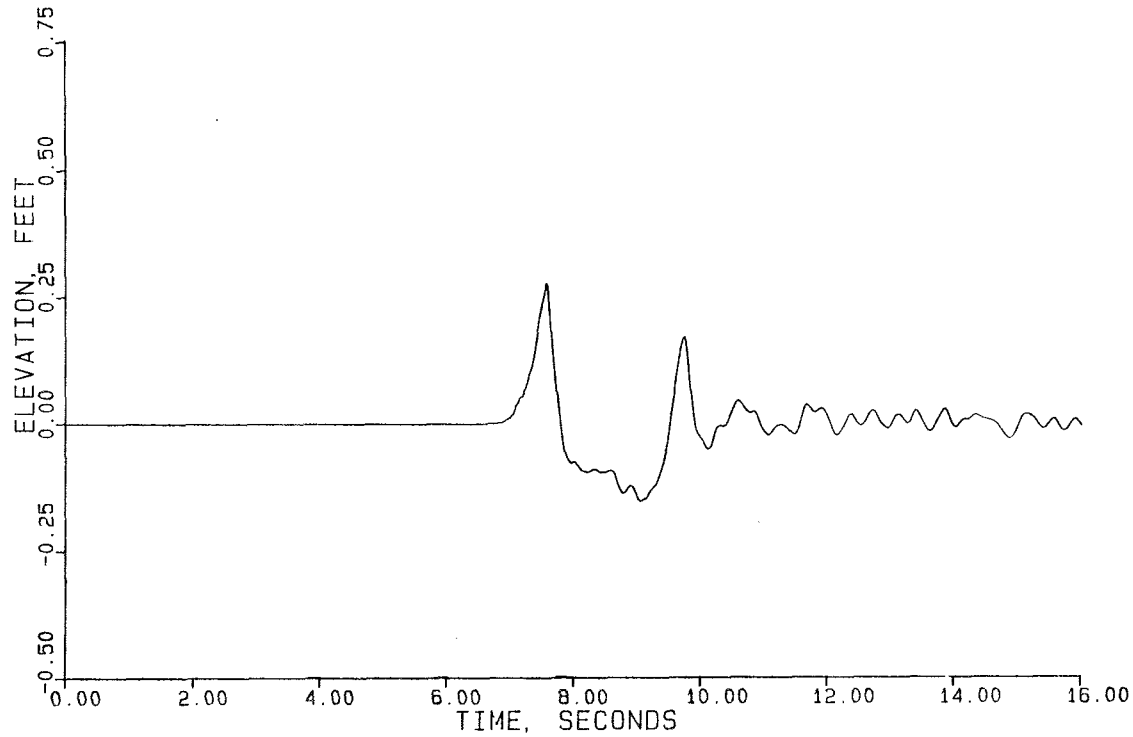
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 3



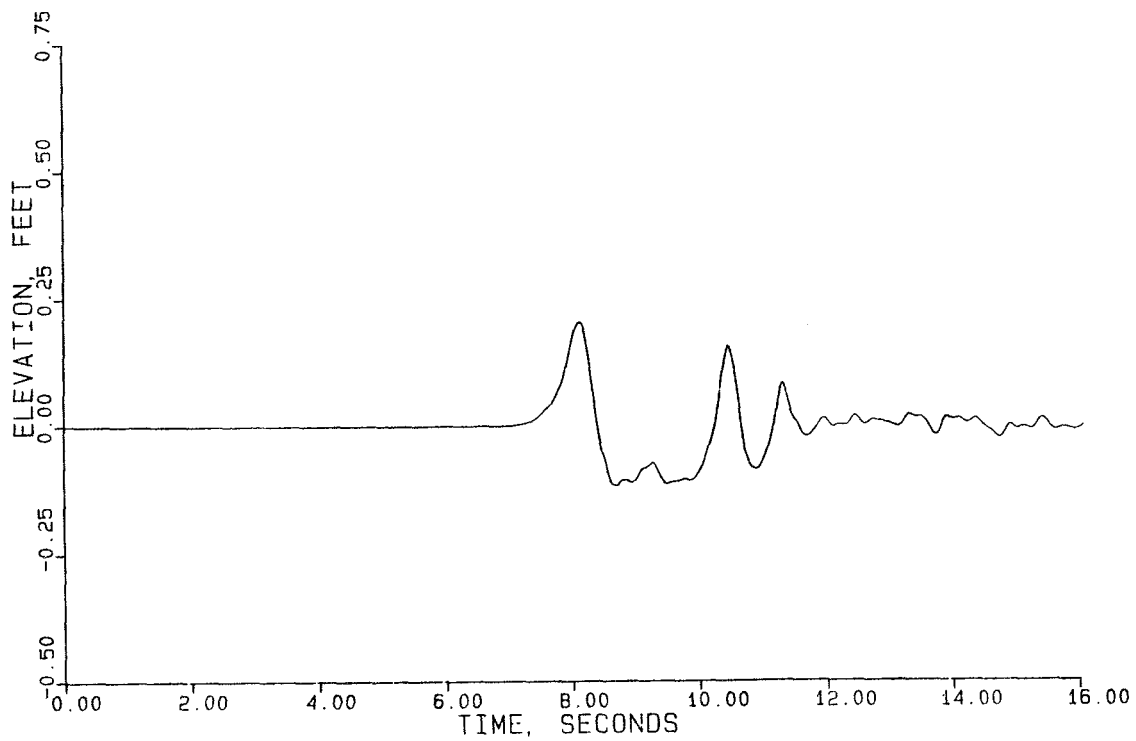
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 4



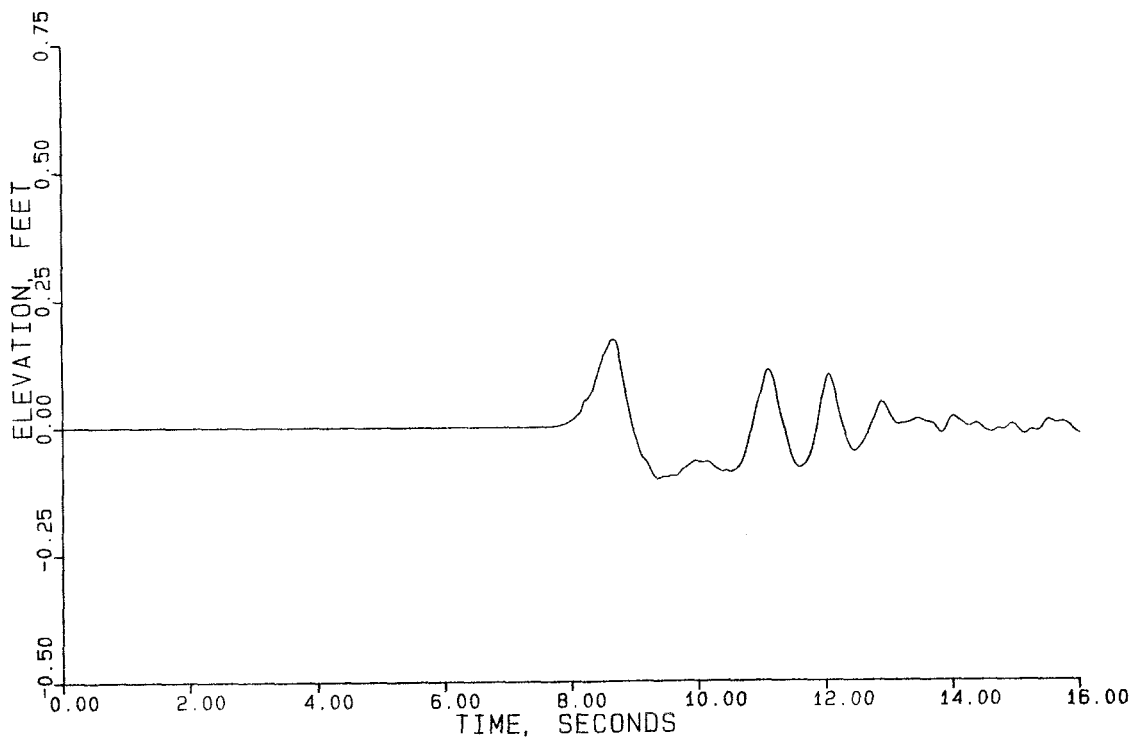
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 5



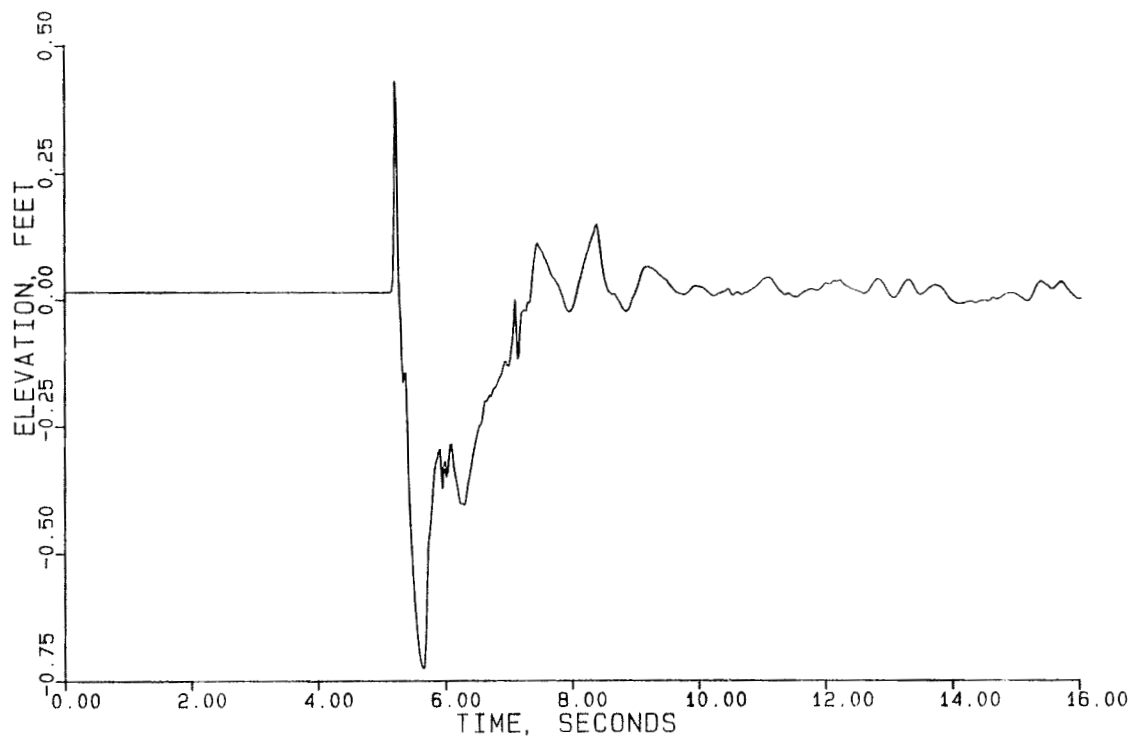
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 6



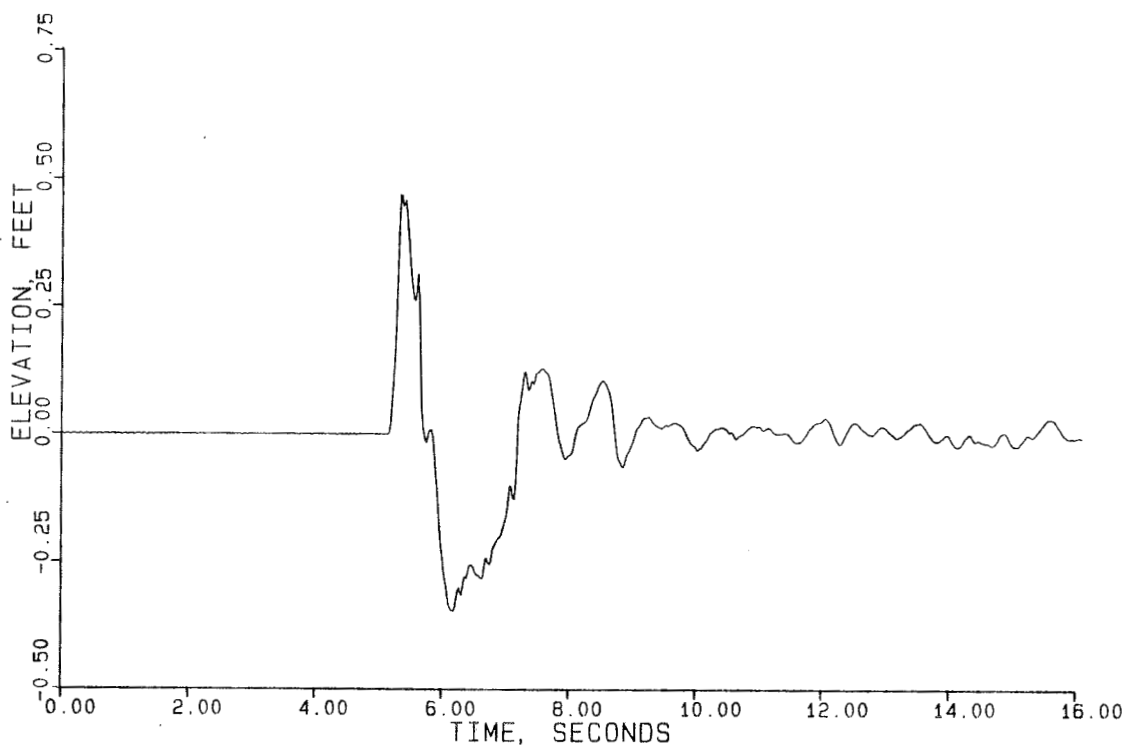
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 7



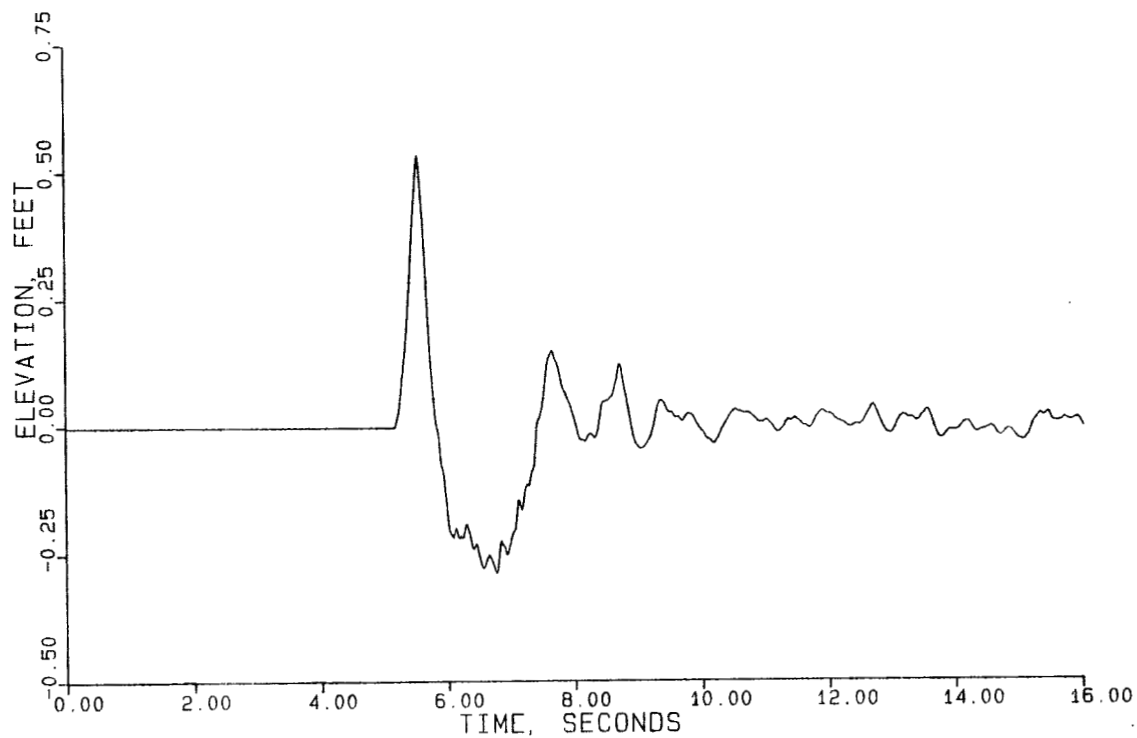
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 21, GAGE 8



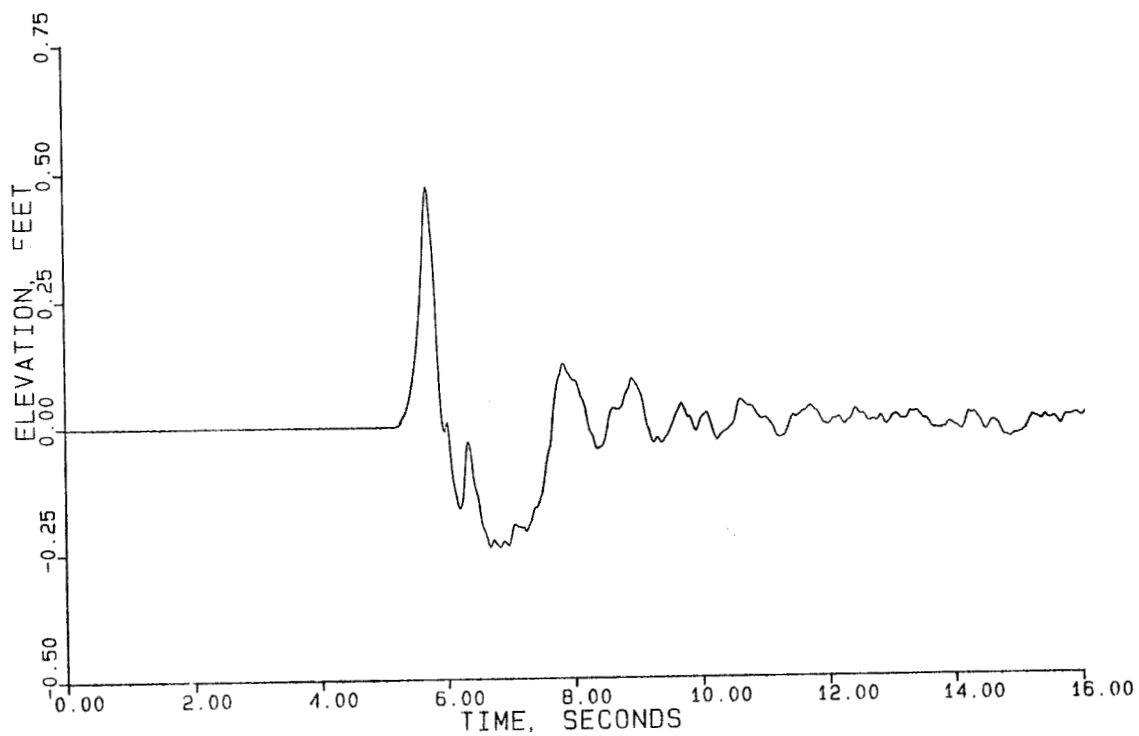
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 1



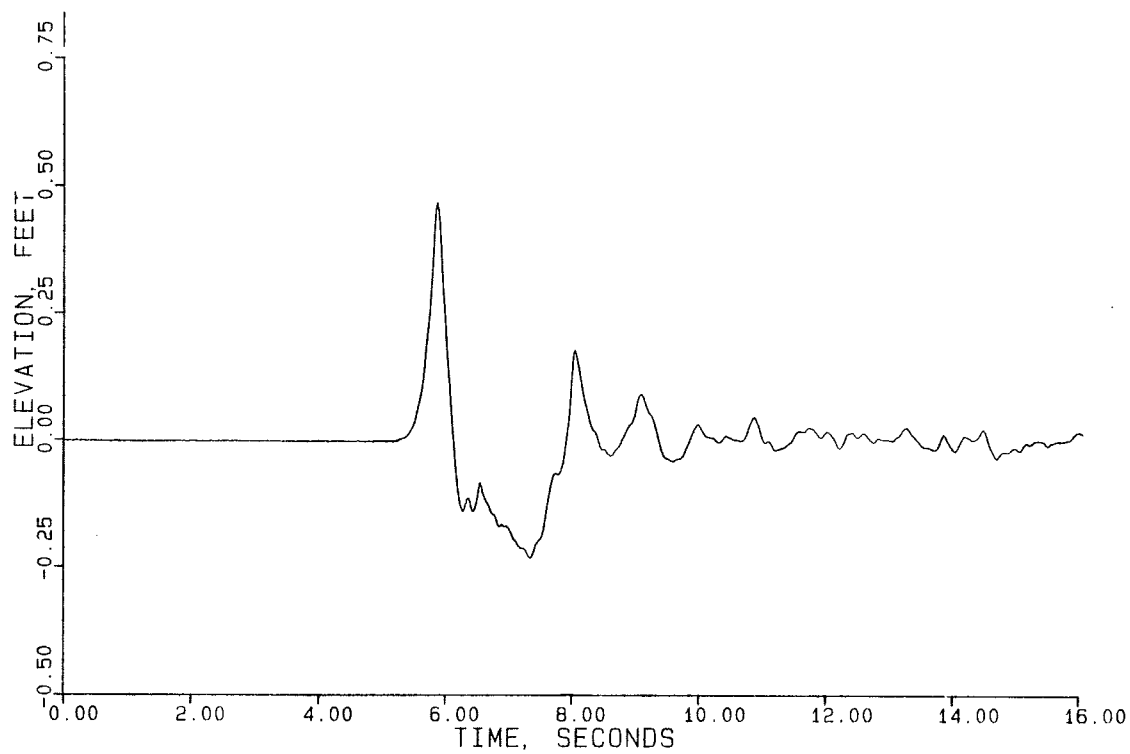
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 2



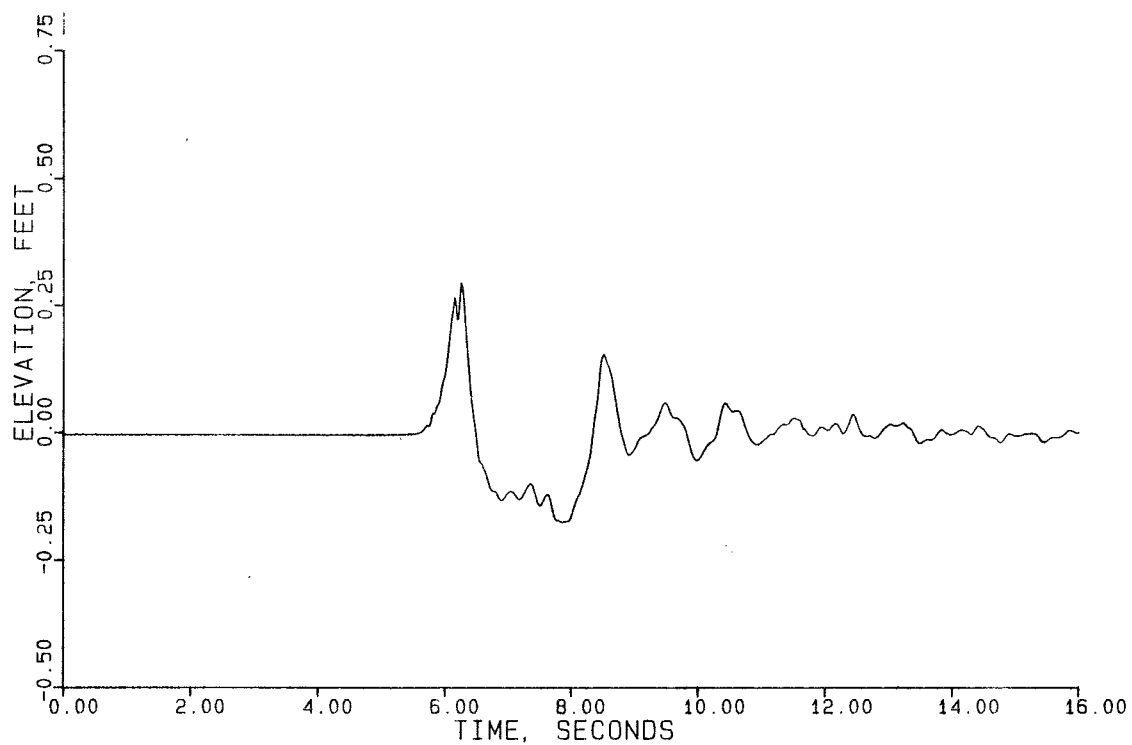
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 3



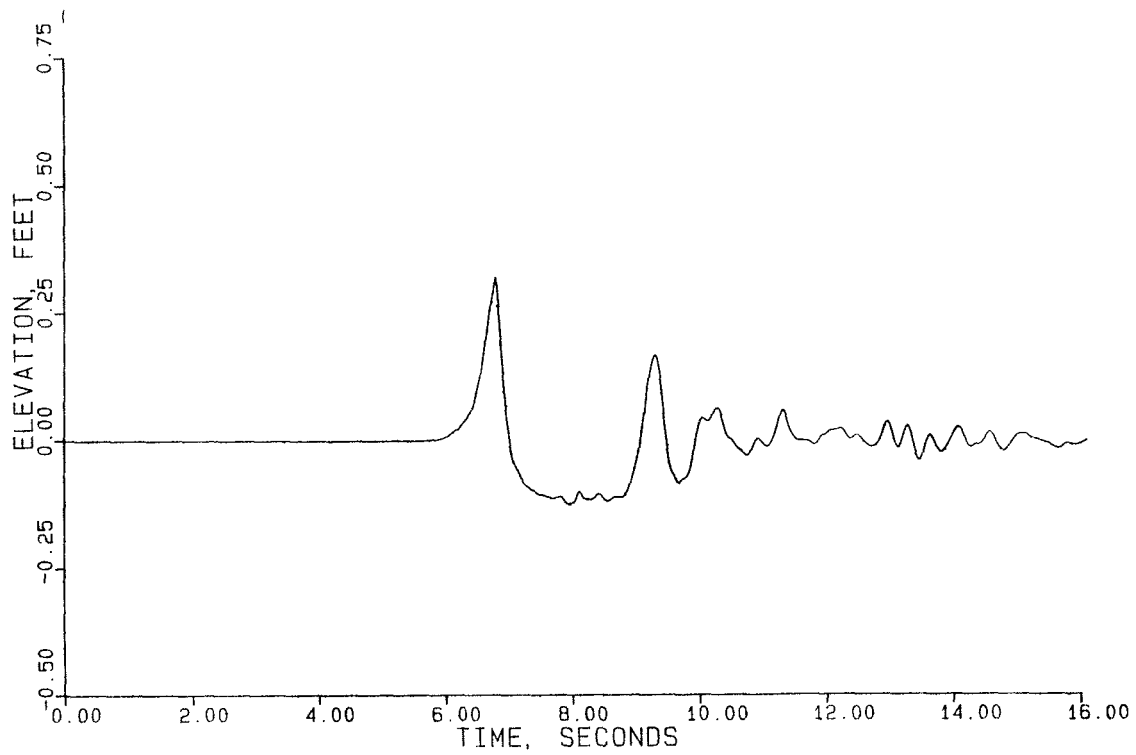
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 4



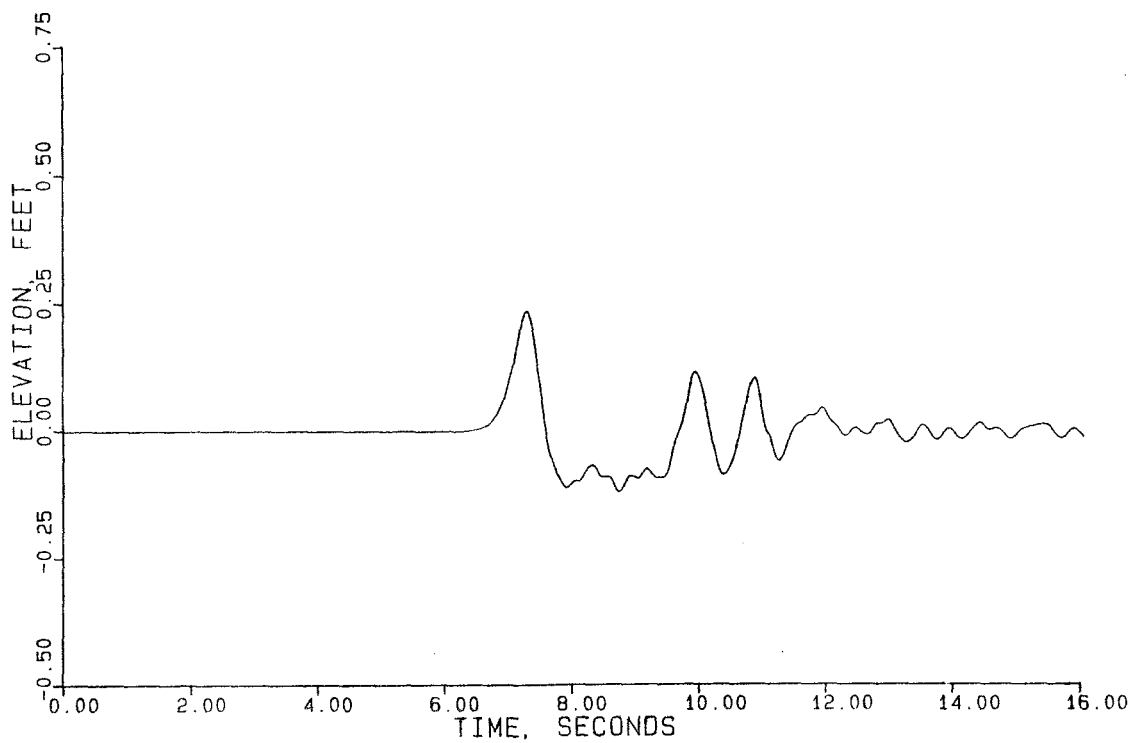
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 6

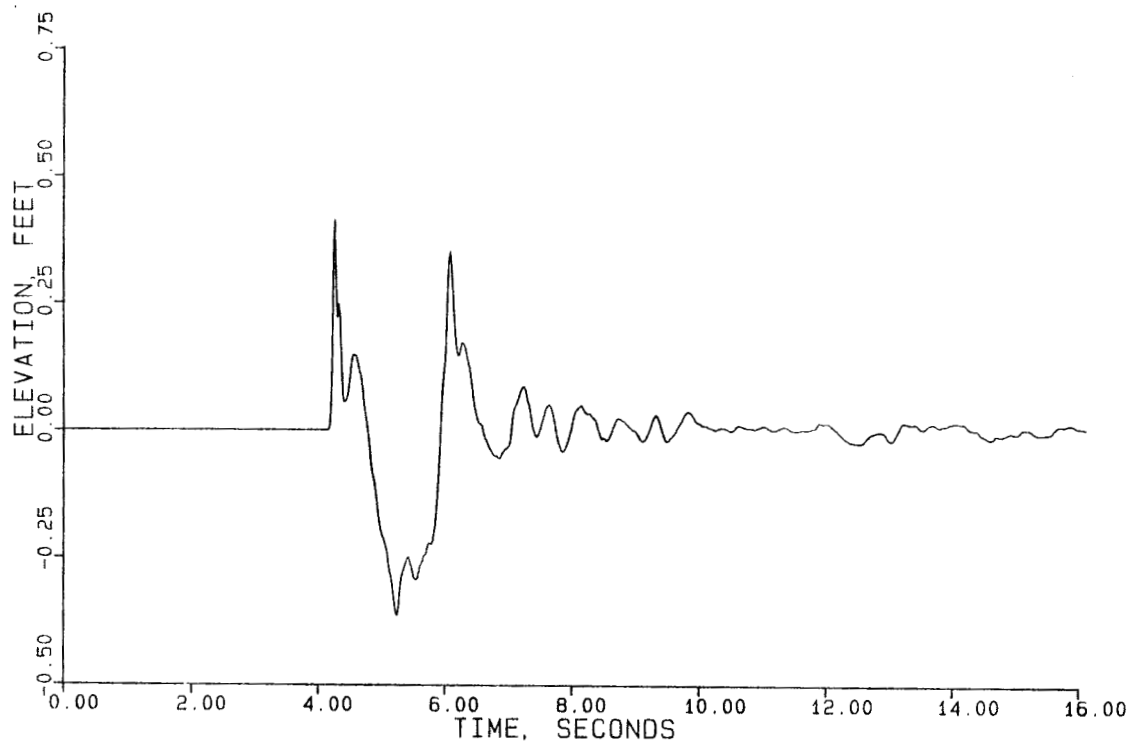


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 7

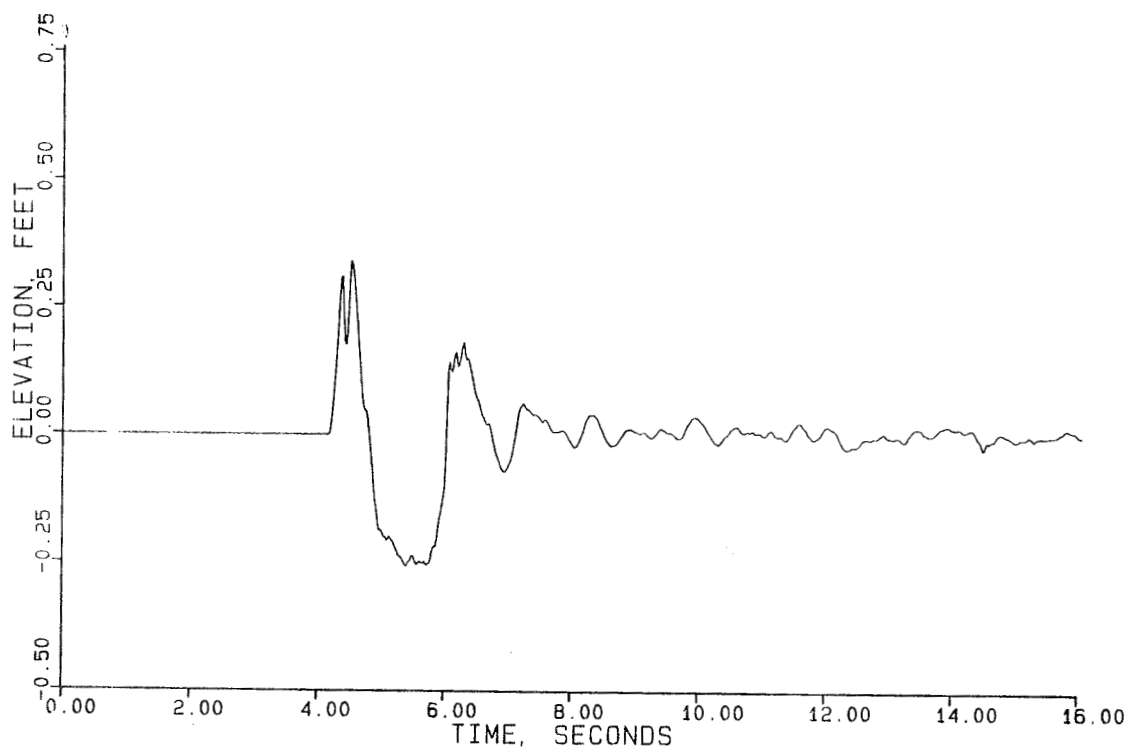


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 22, GAGE 8

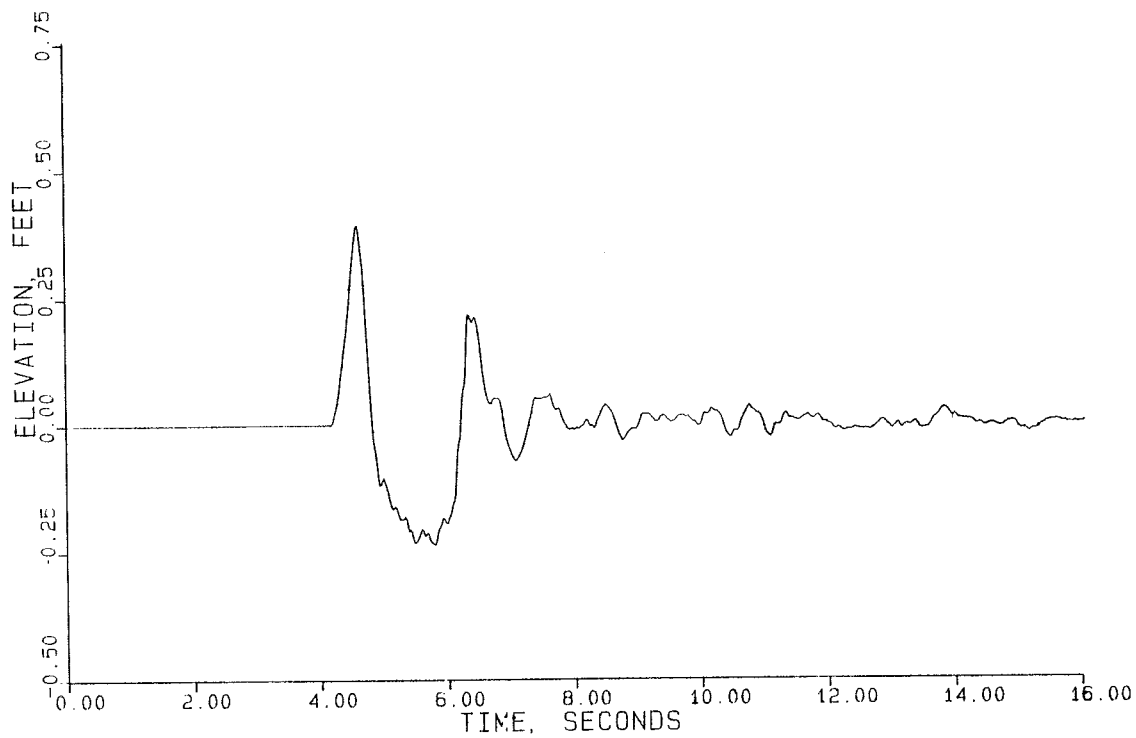




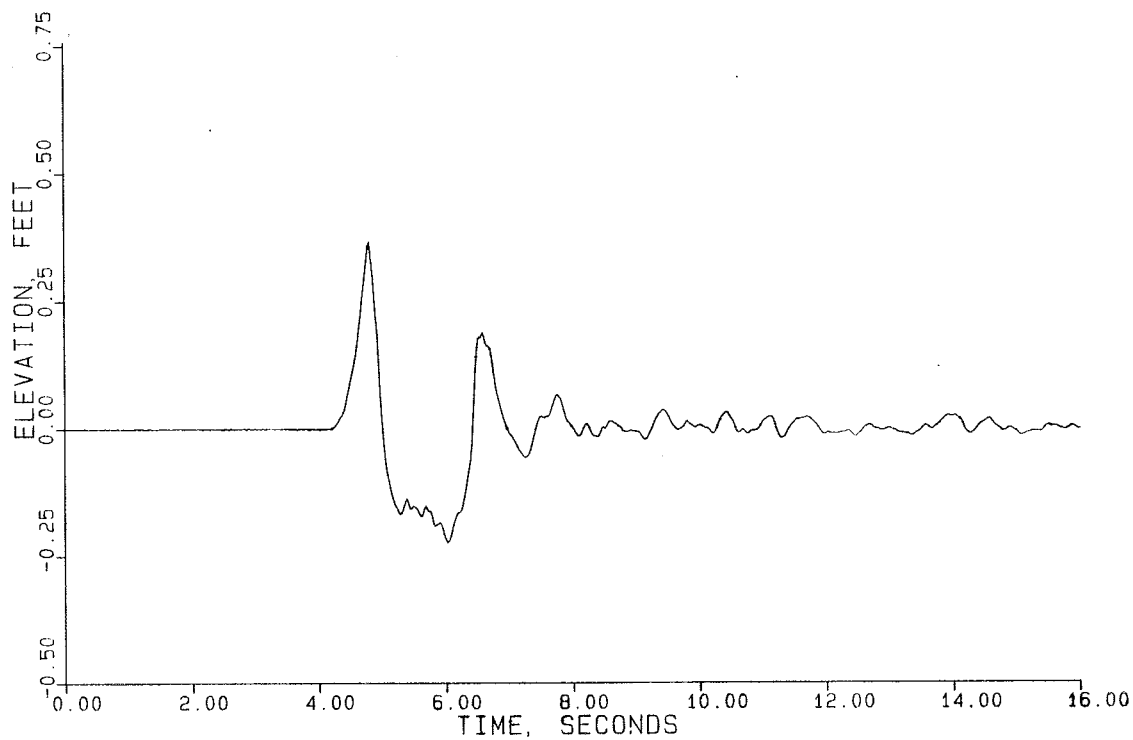
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 1



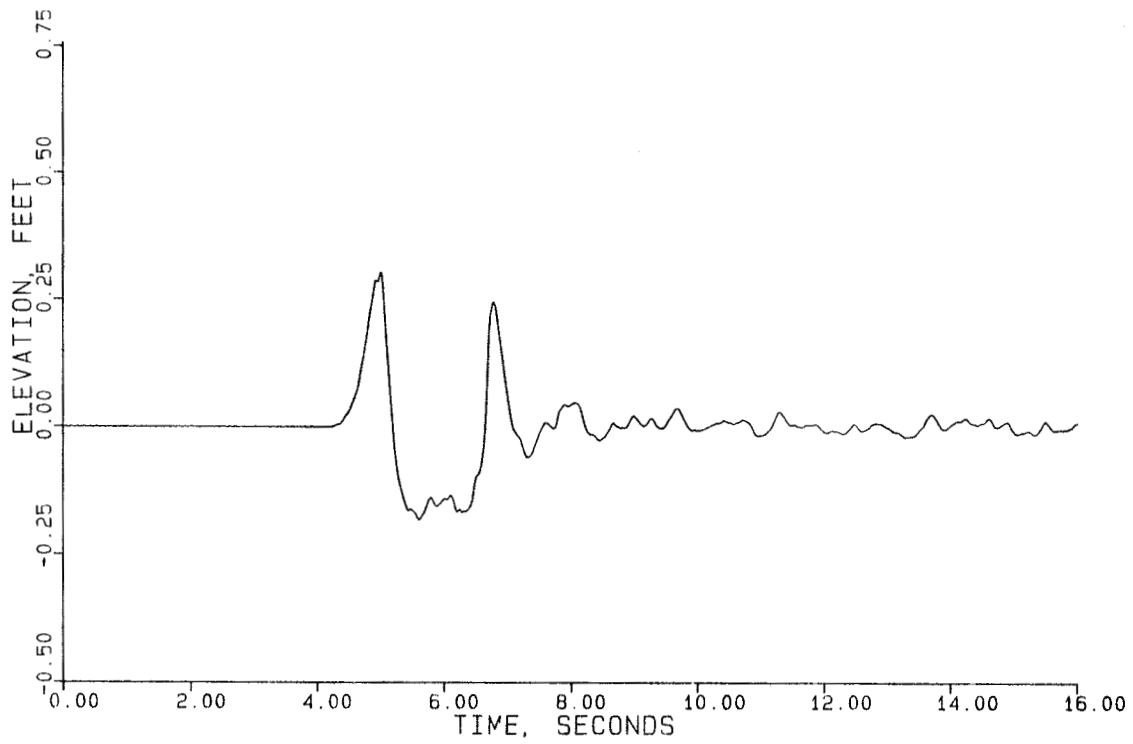
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 2



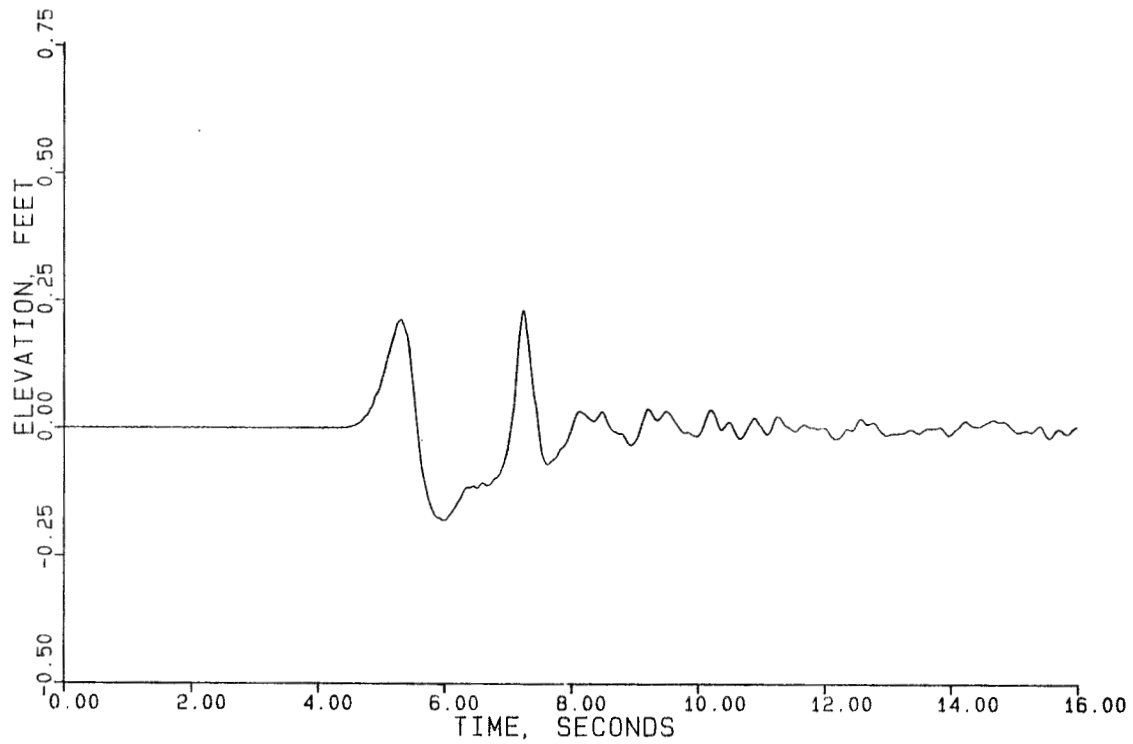
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 3



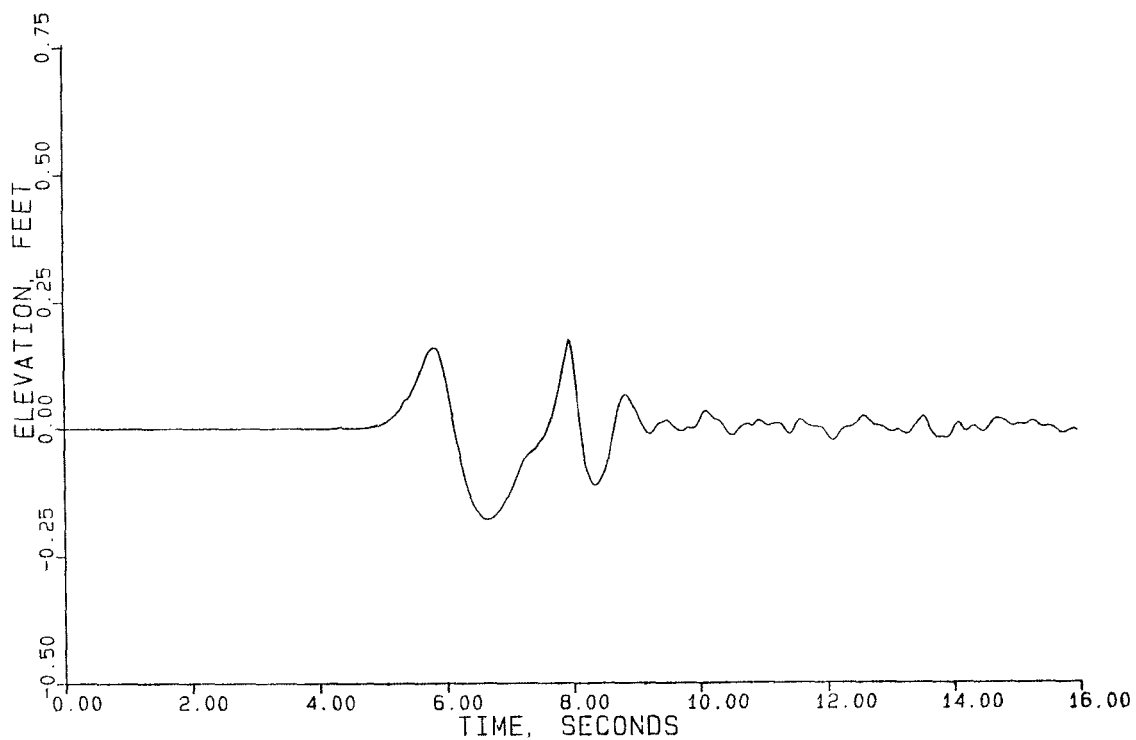
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 4



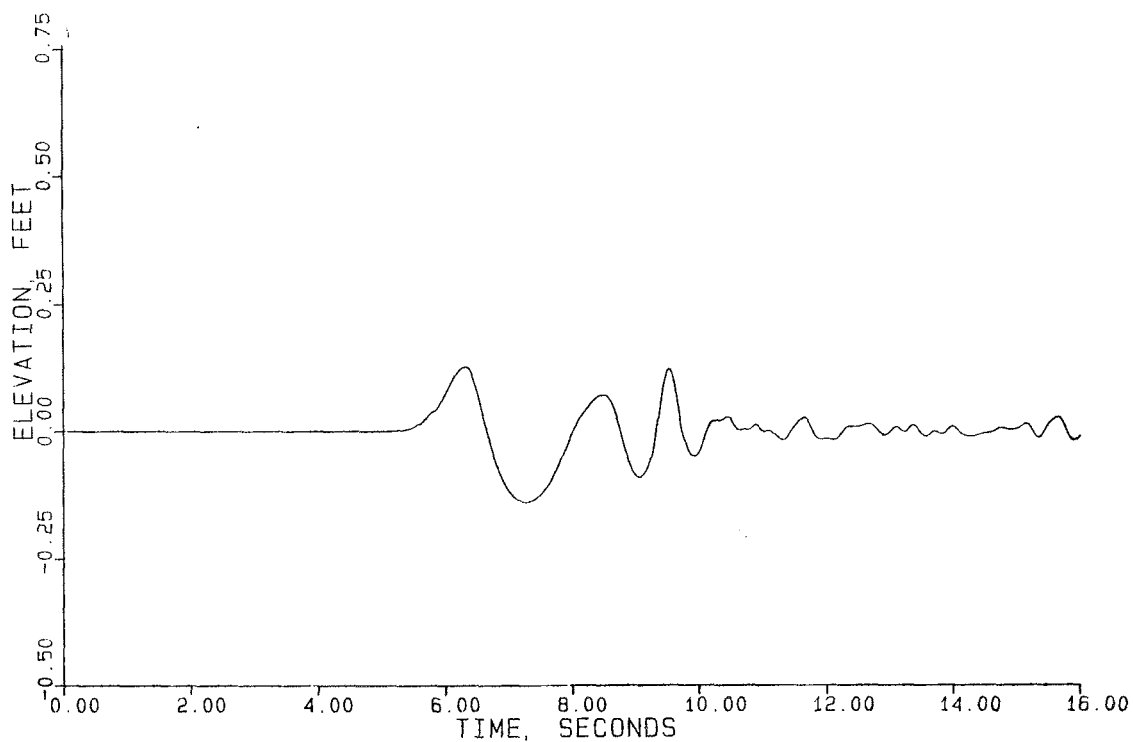
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 5



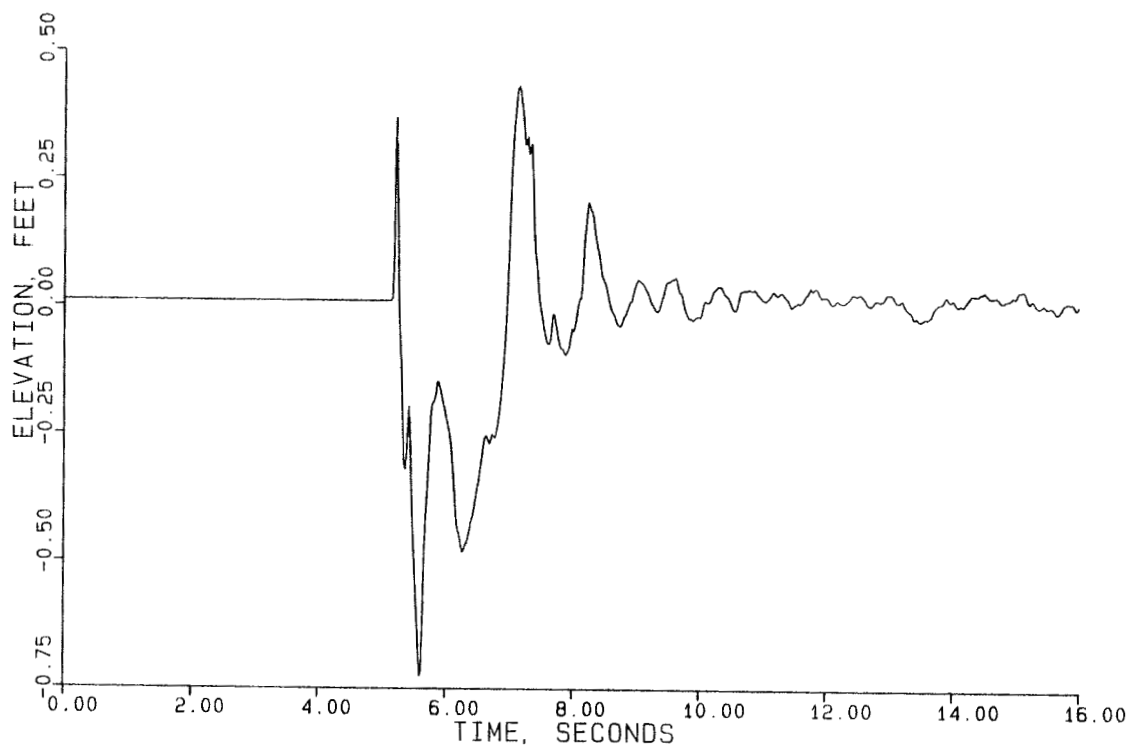
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 6



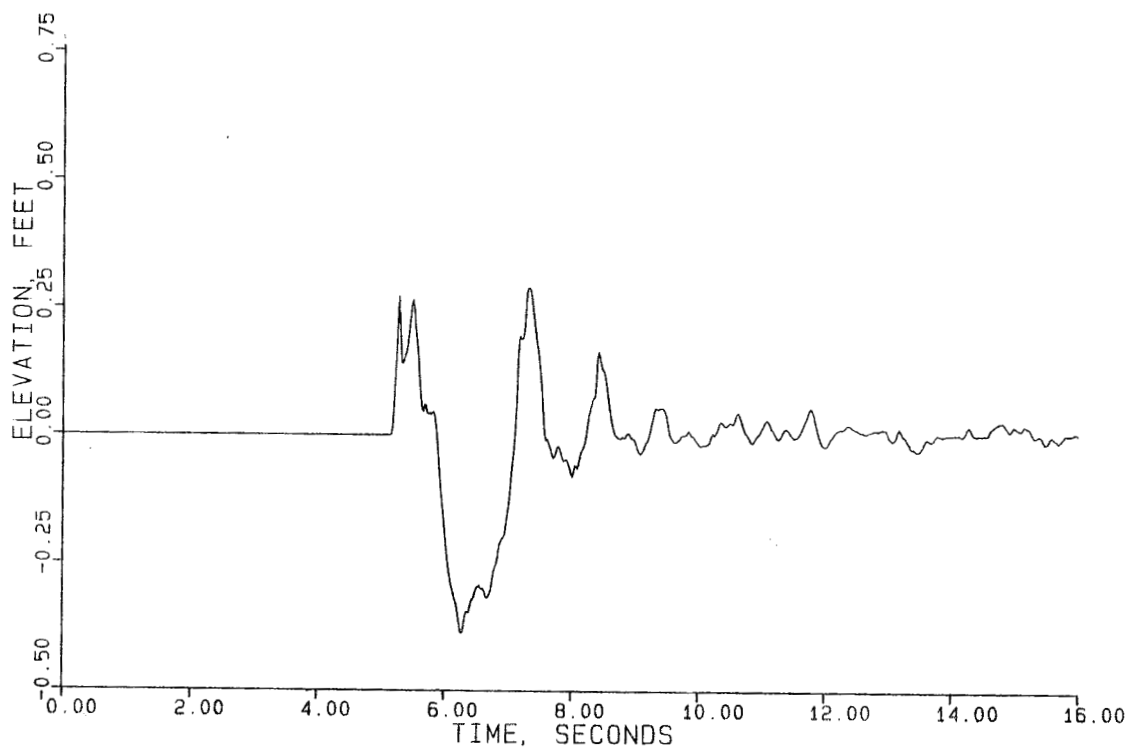
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 7



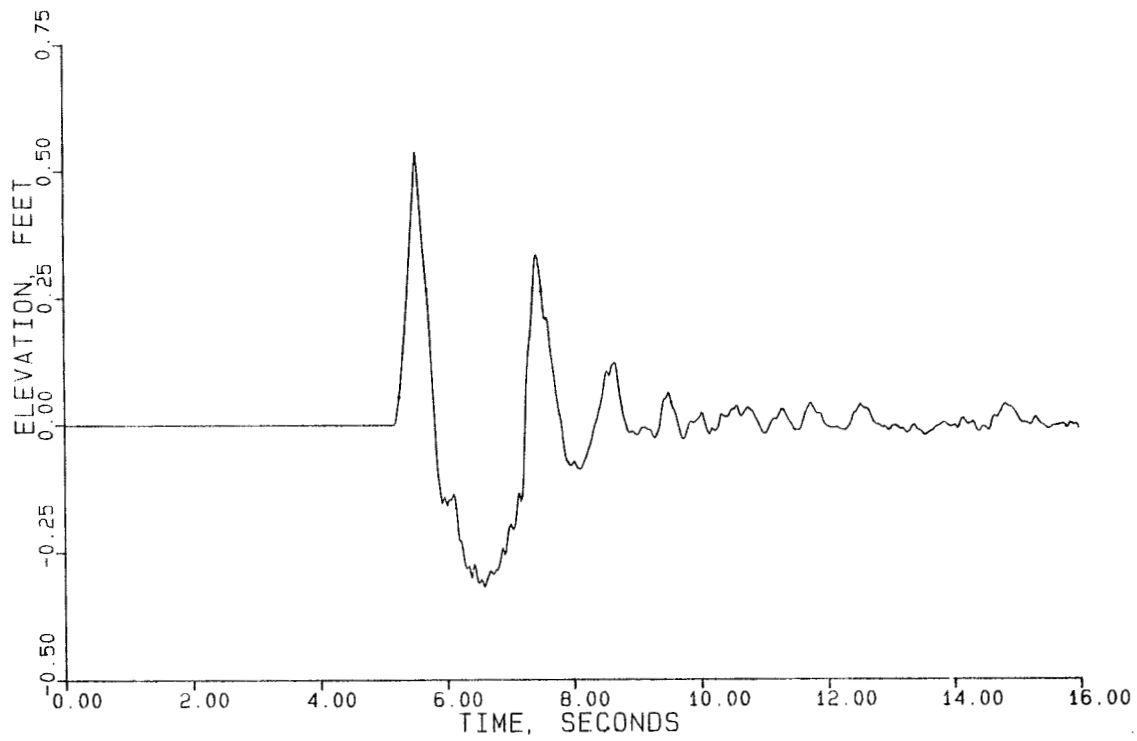
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 23, GAGE 8



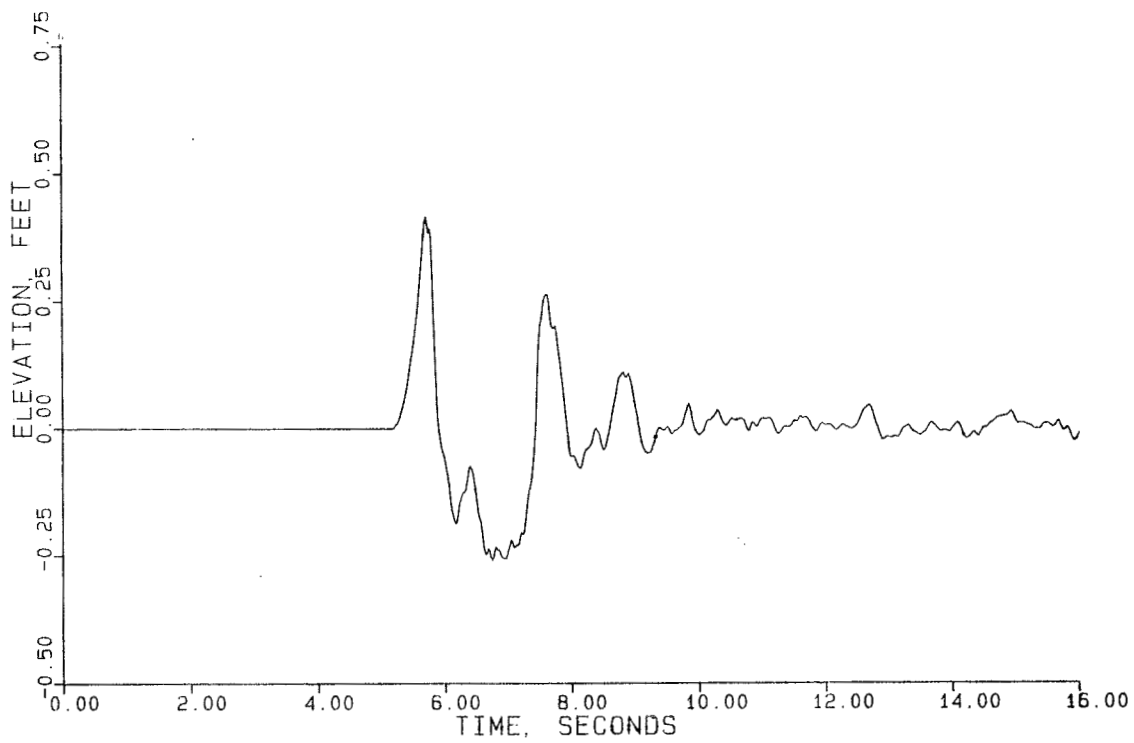
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 1



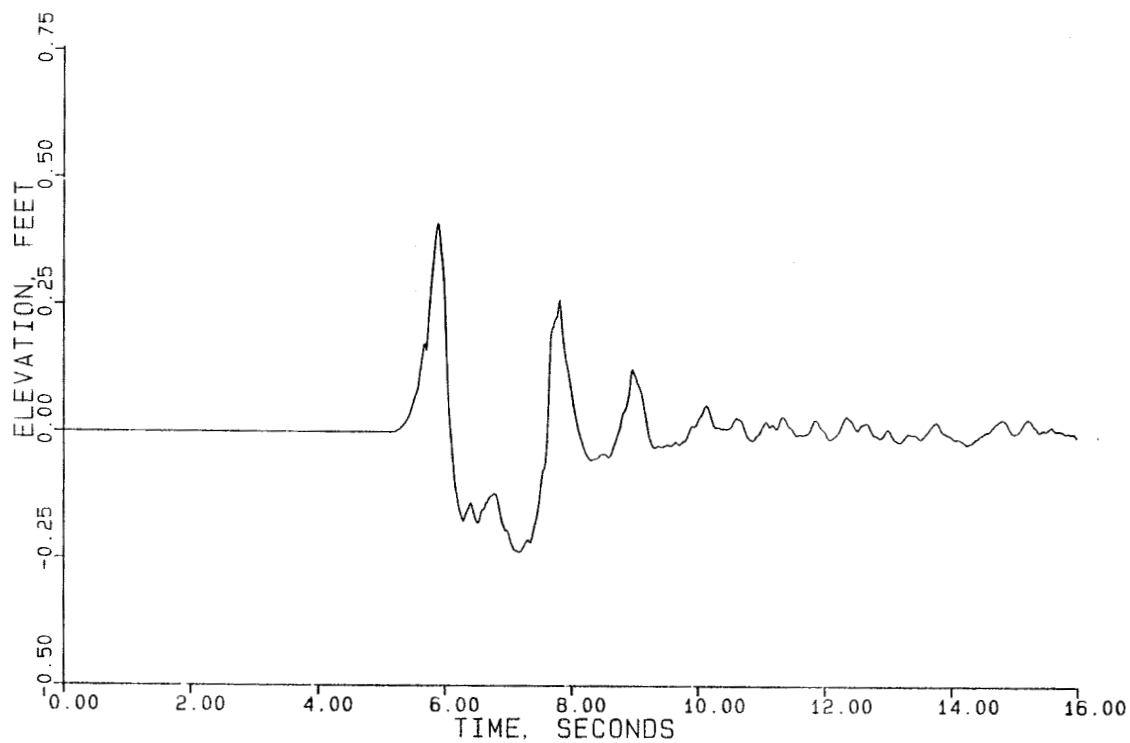
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 2



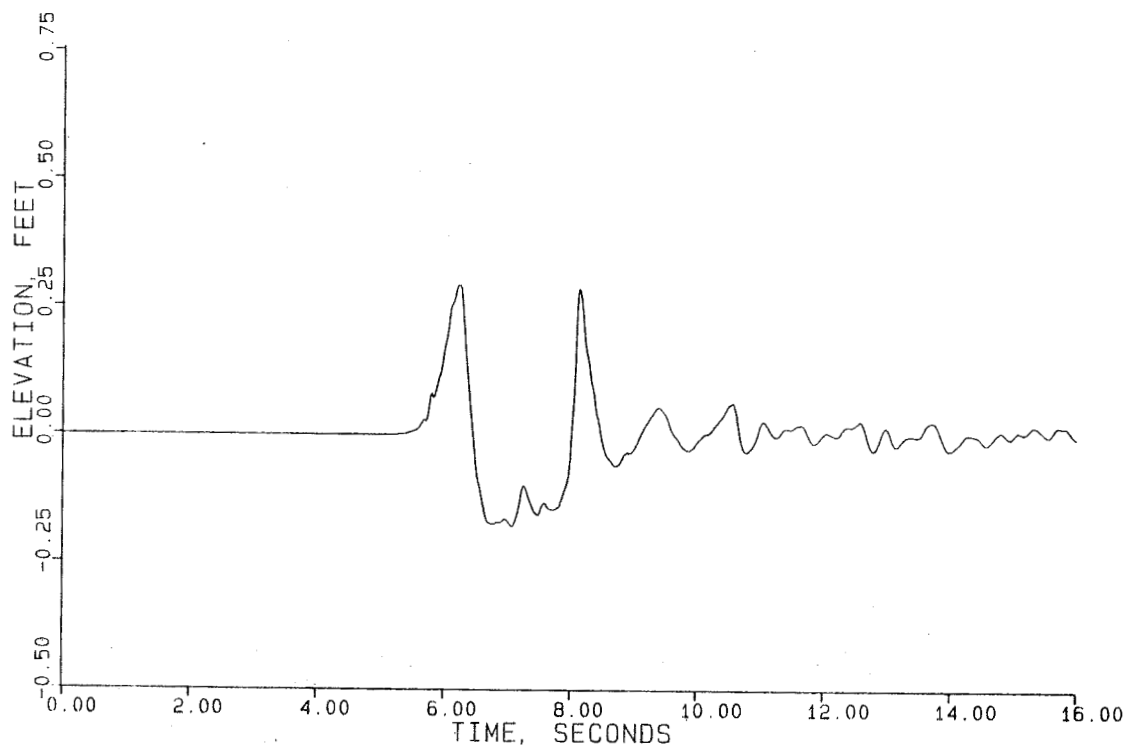
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 3



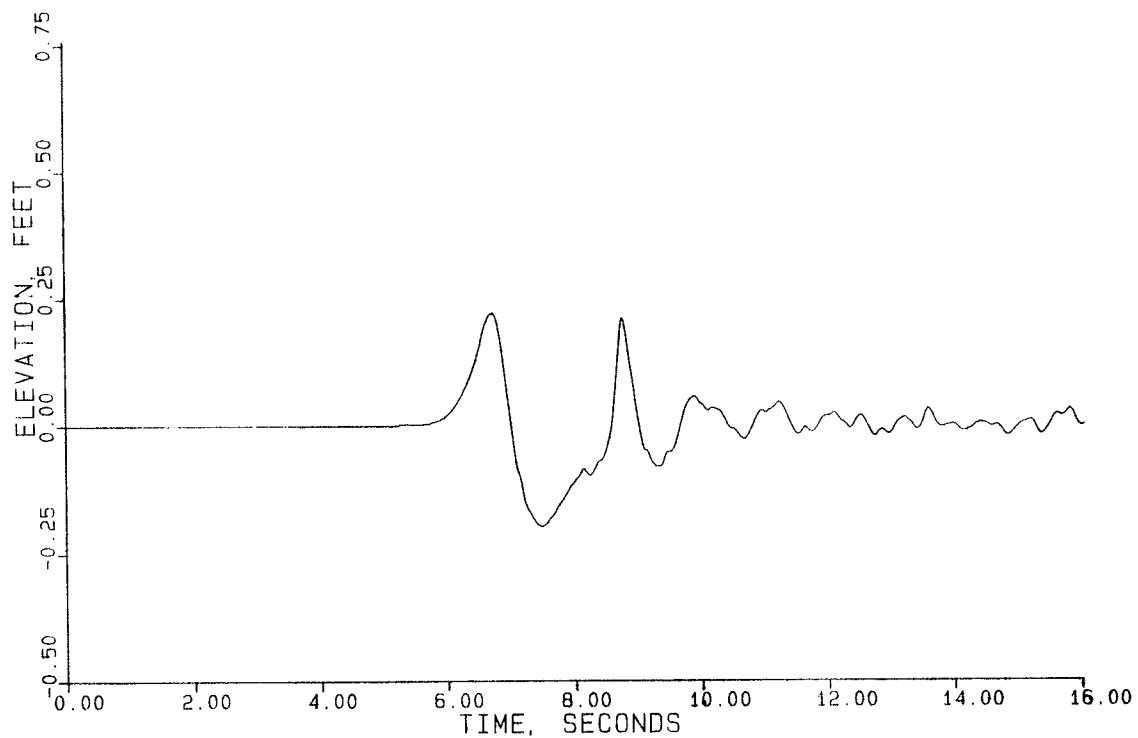
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 4



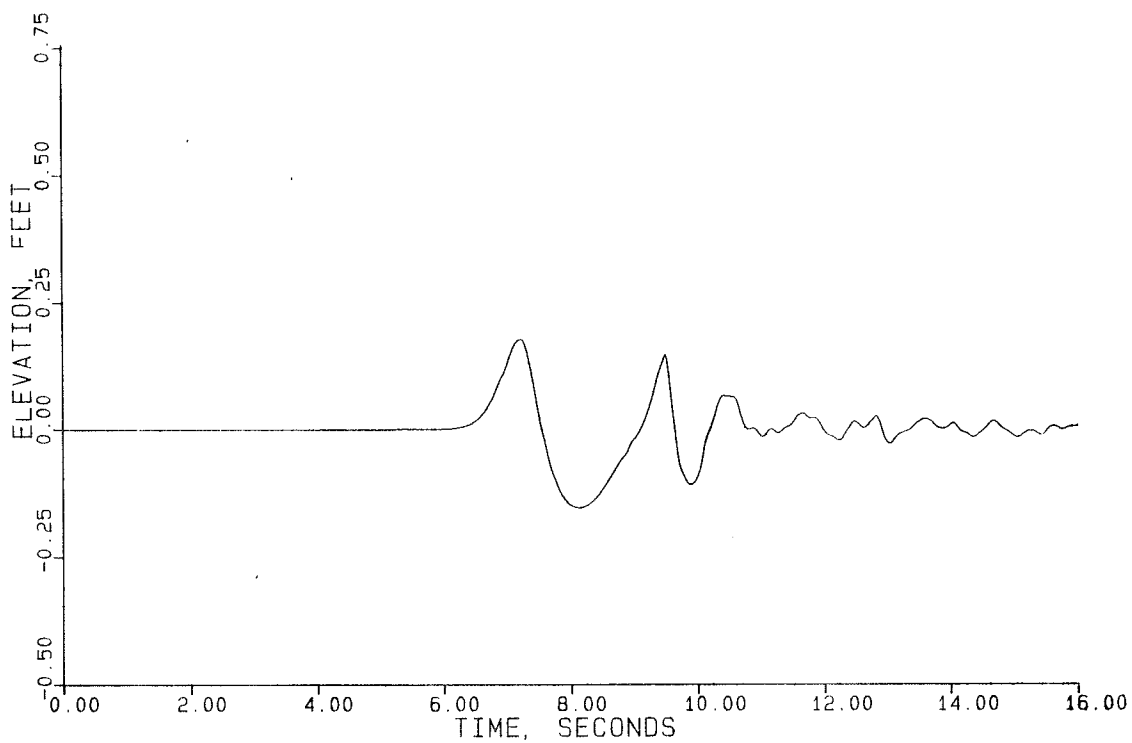
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 5



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 6

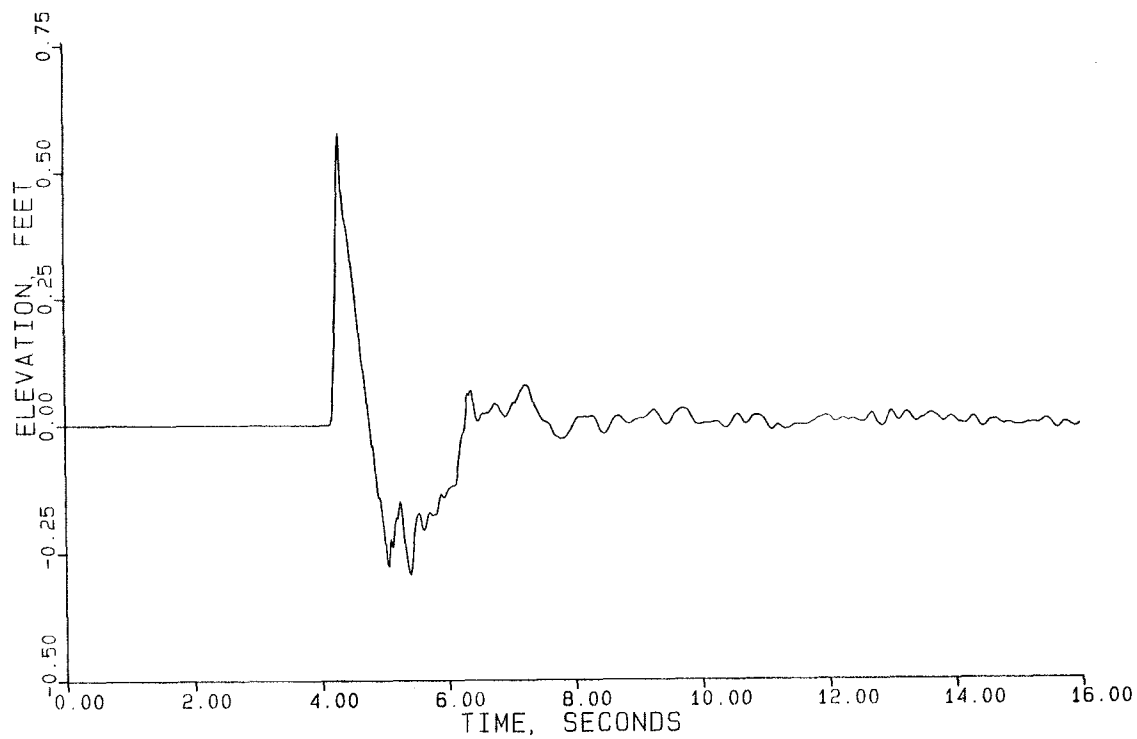


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 7

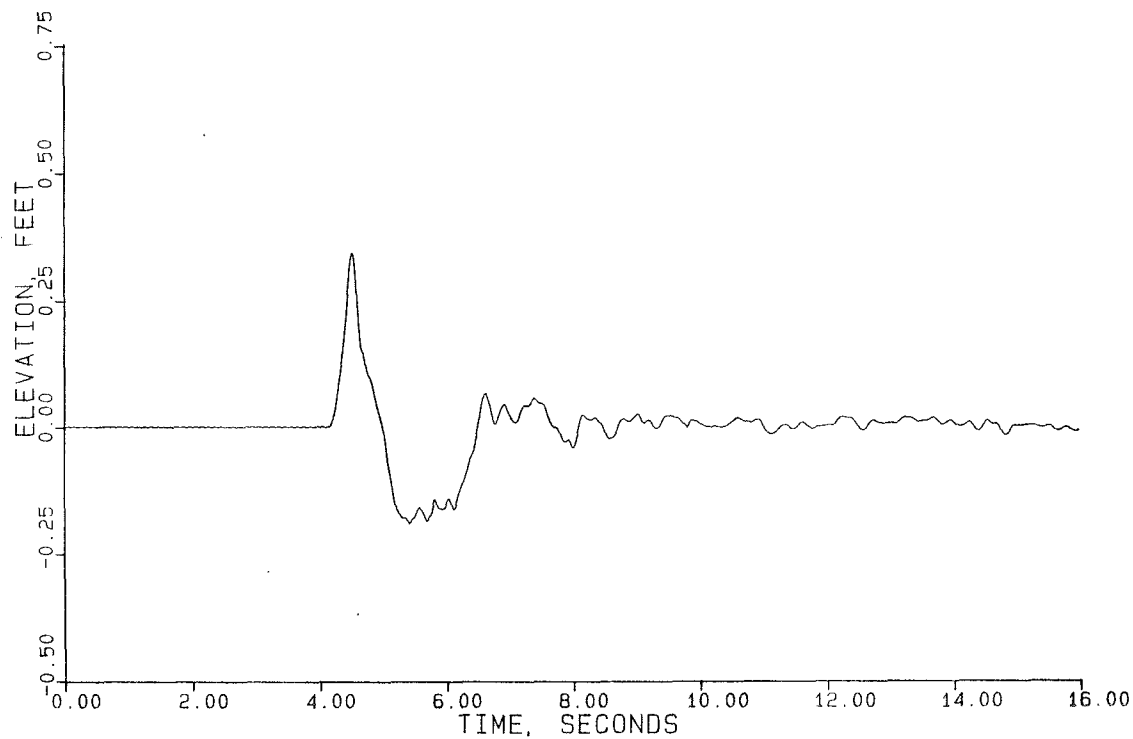


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 24, GAGE 8

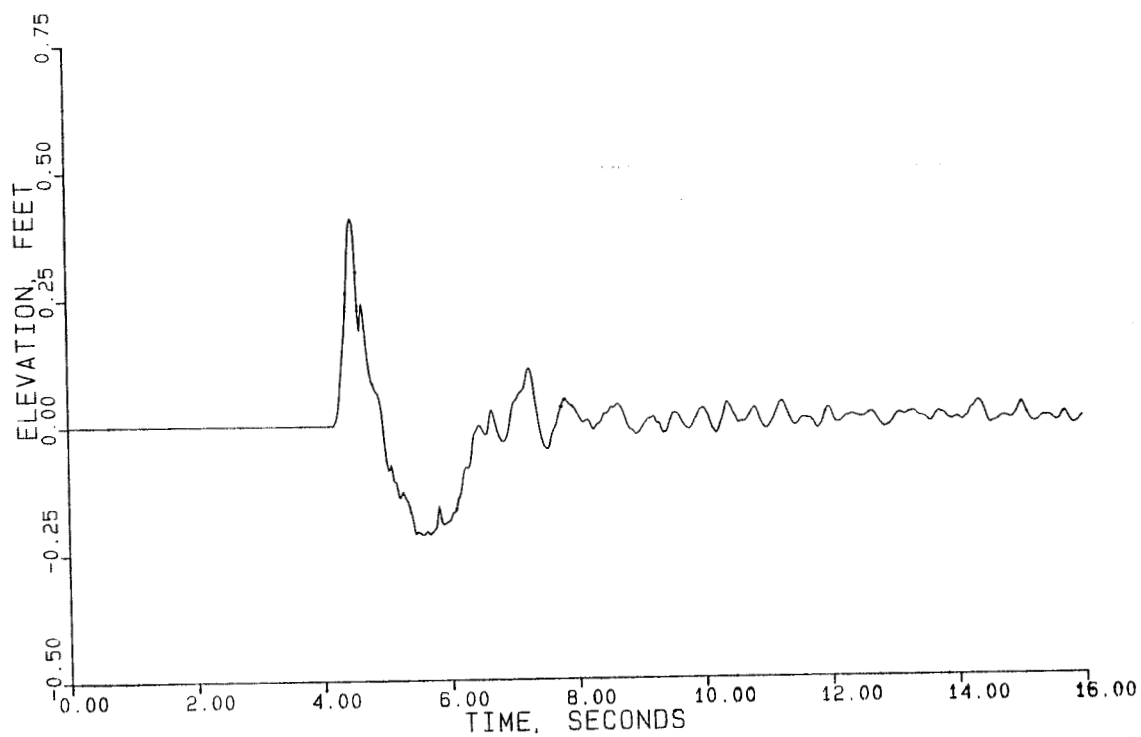




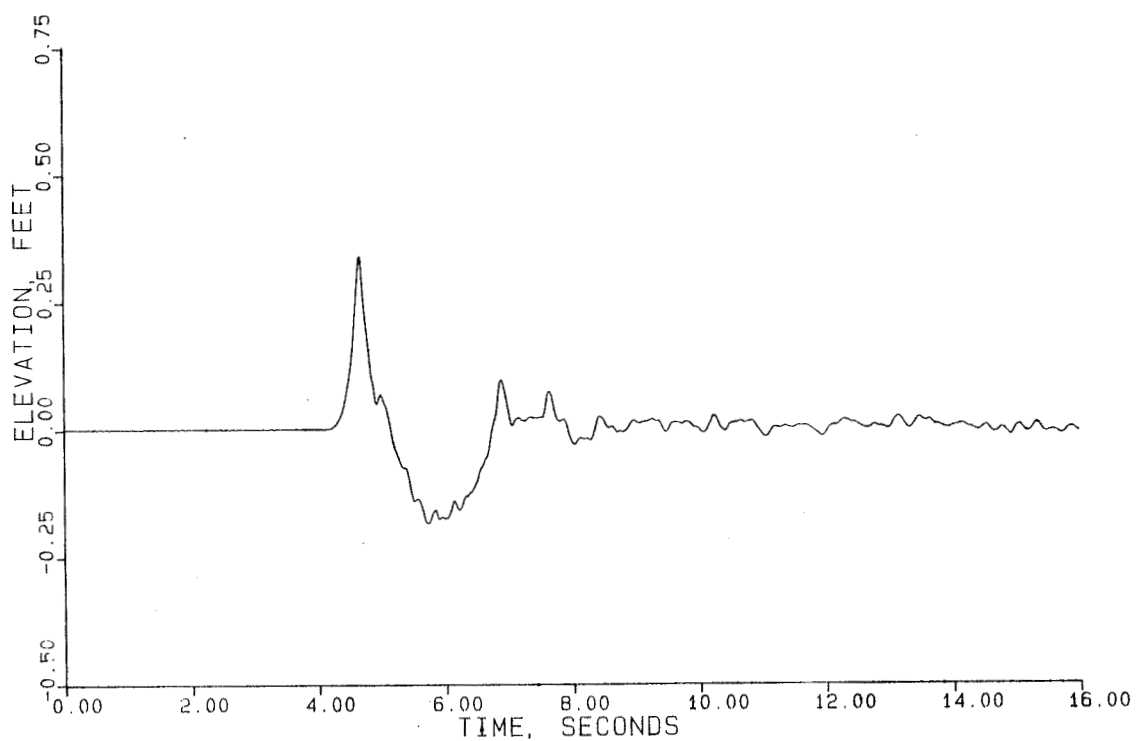
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 1



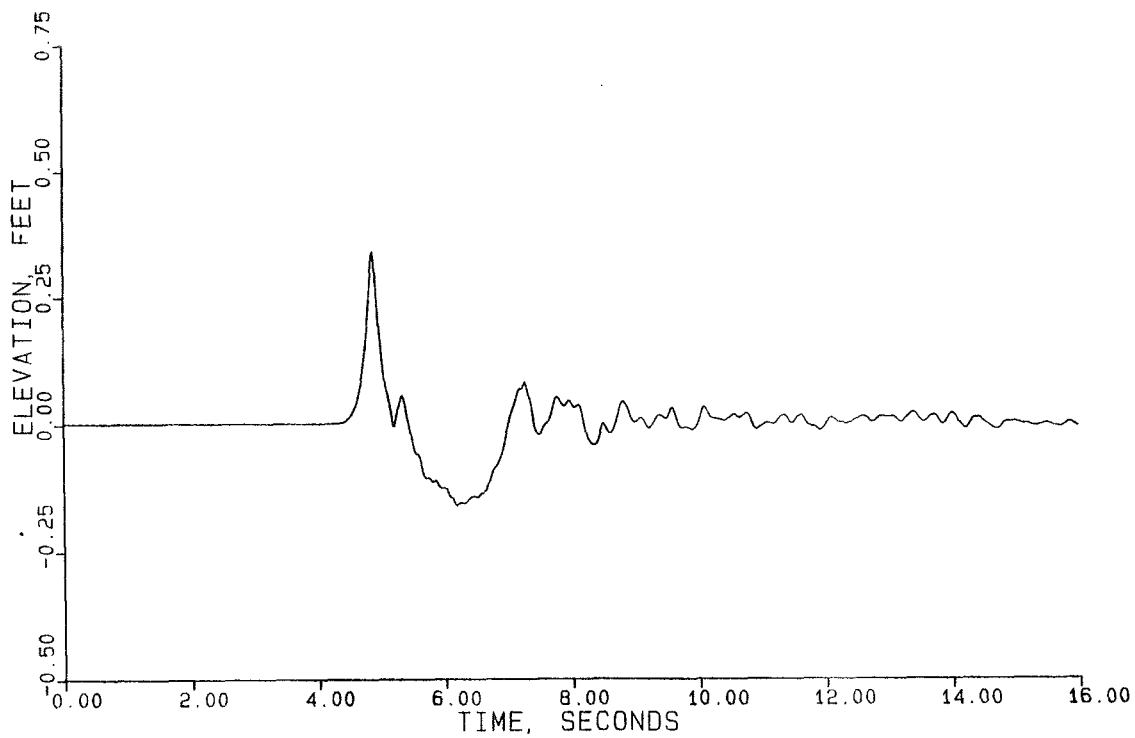
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 2



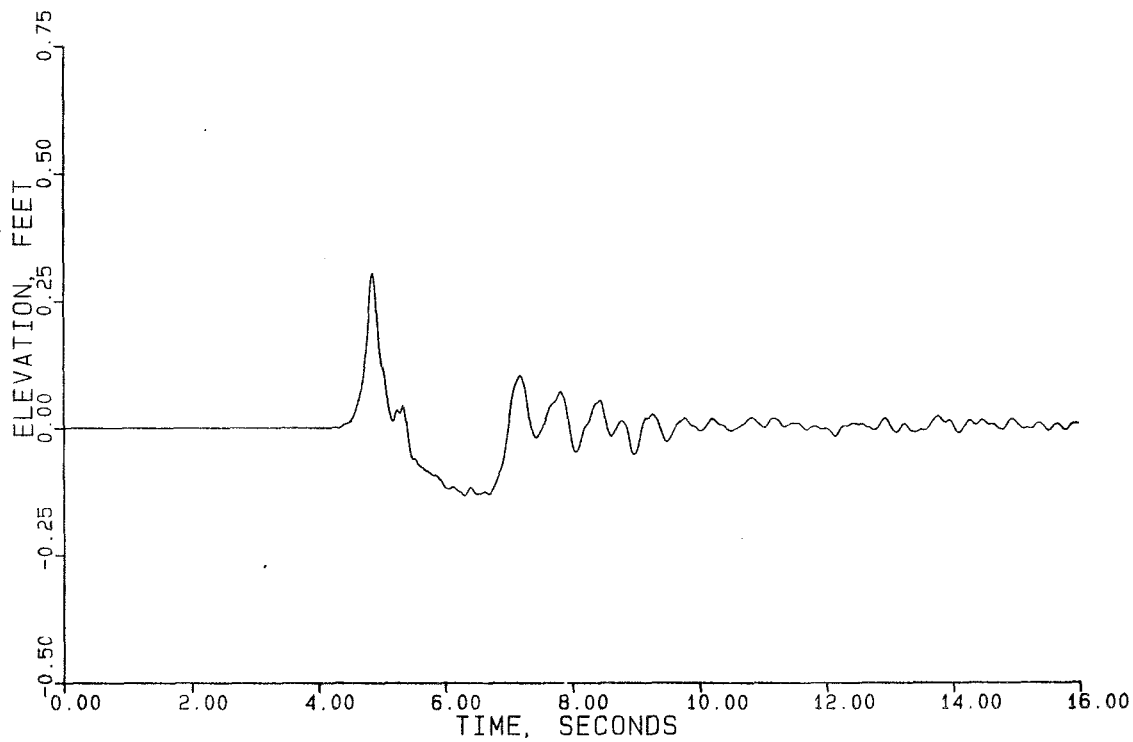
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 2A



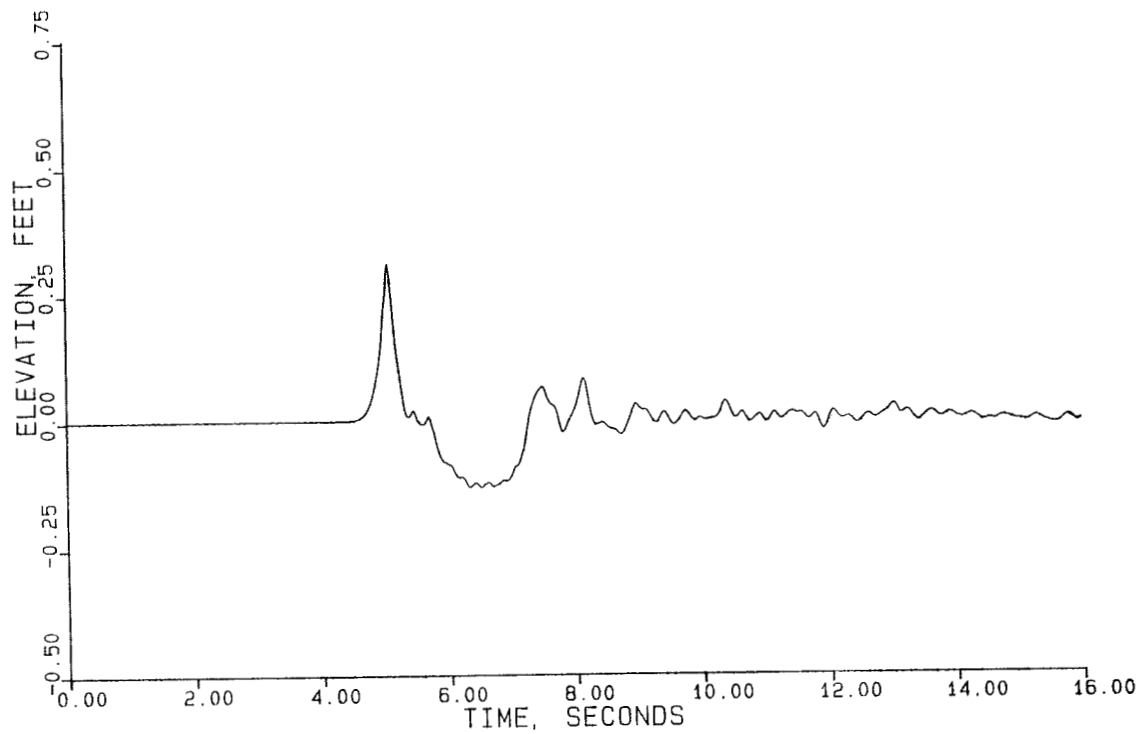
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 3



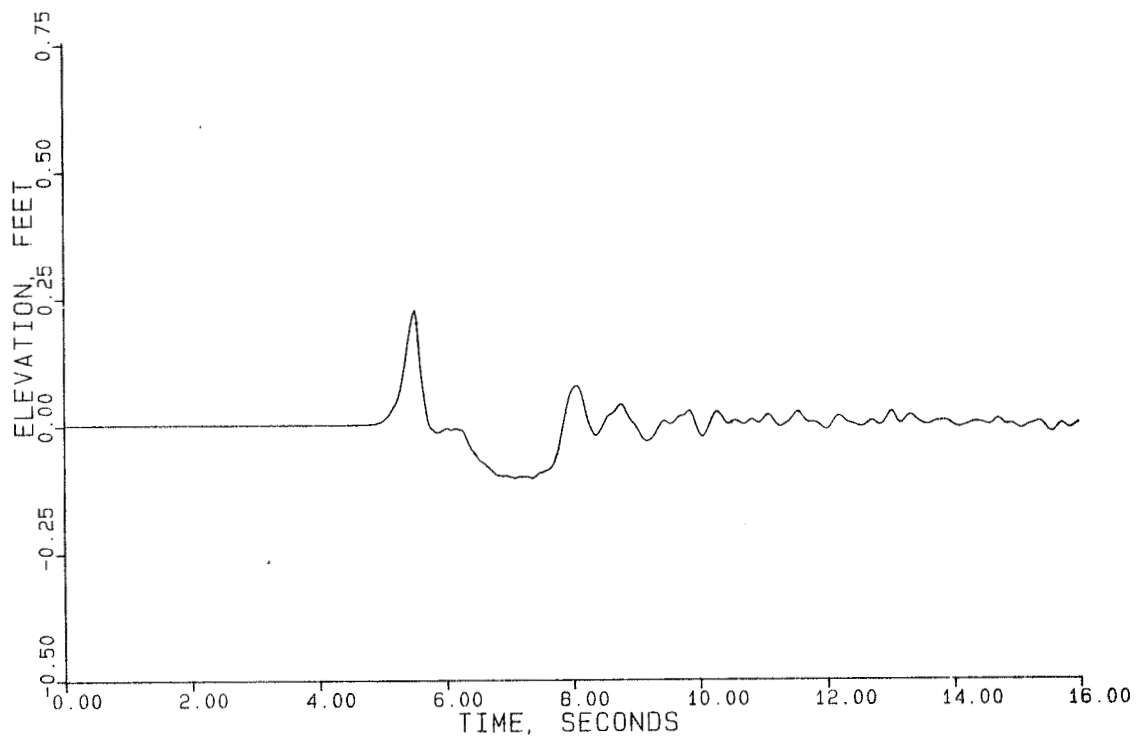
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 4



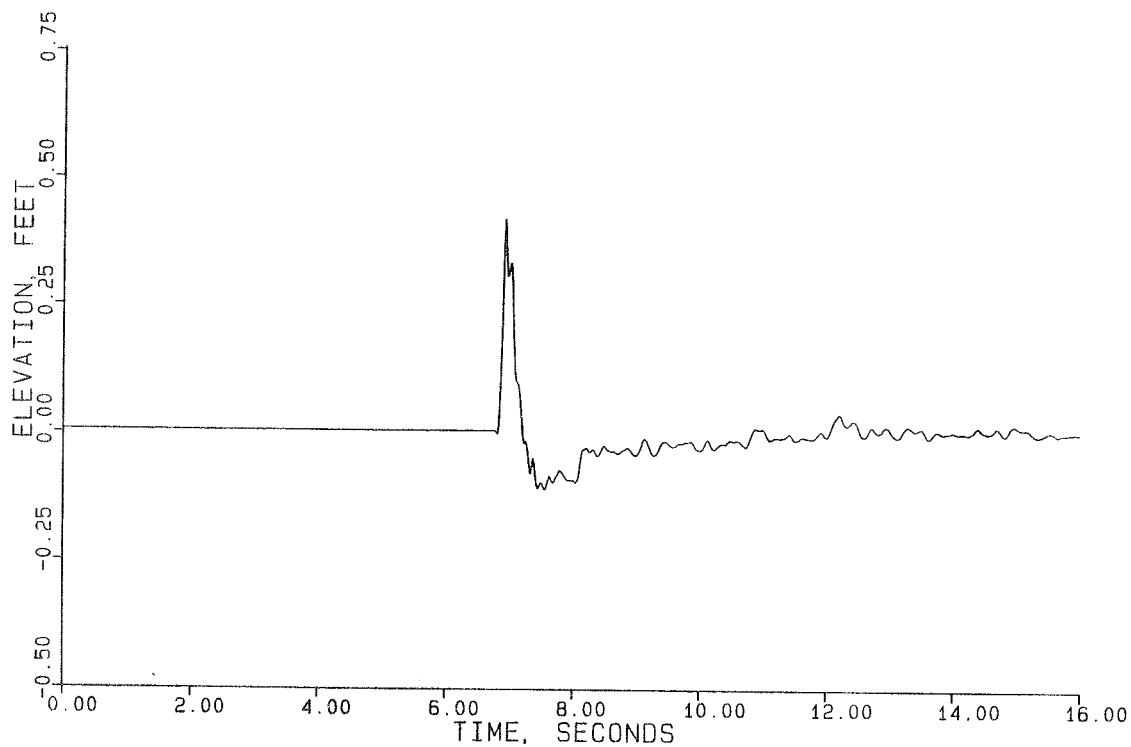
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 4A



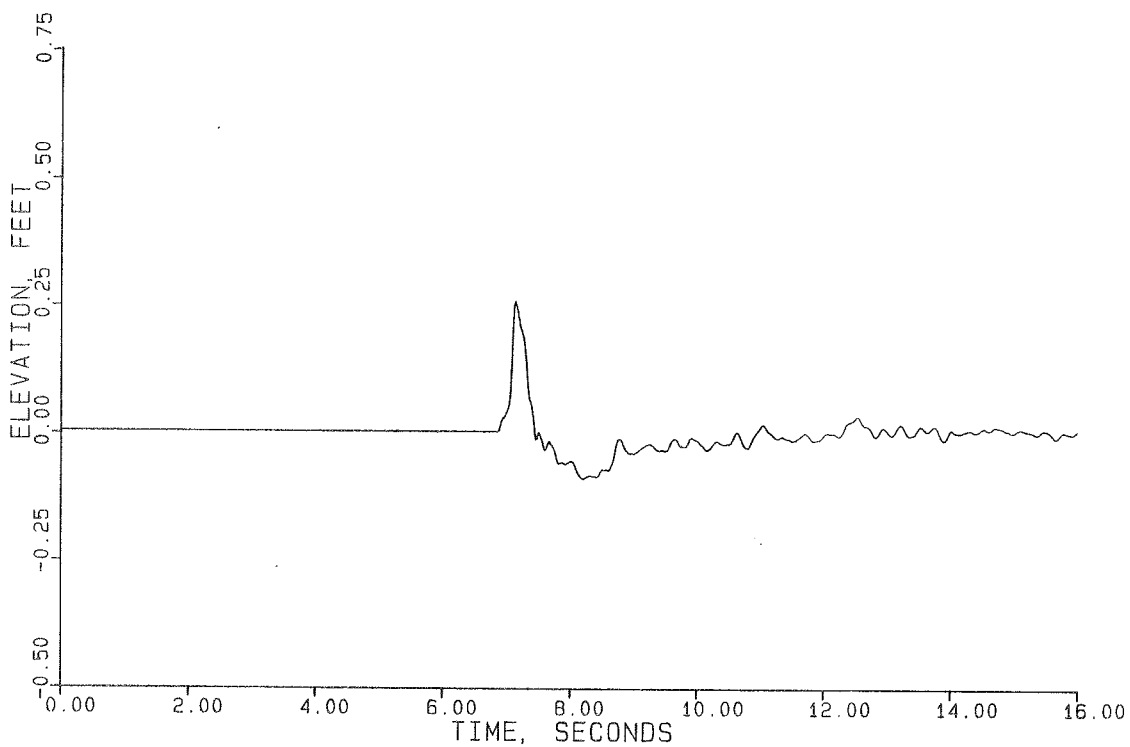
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 5



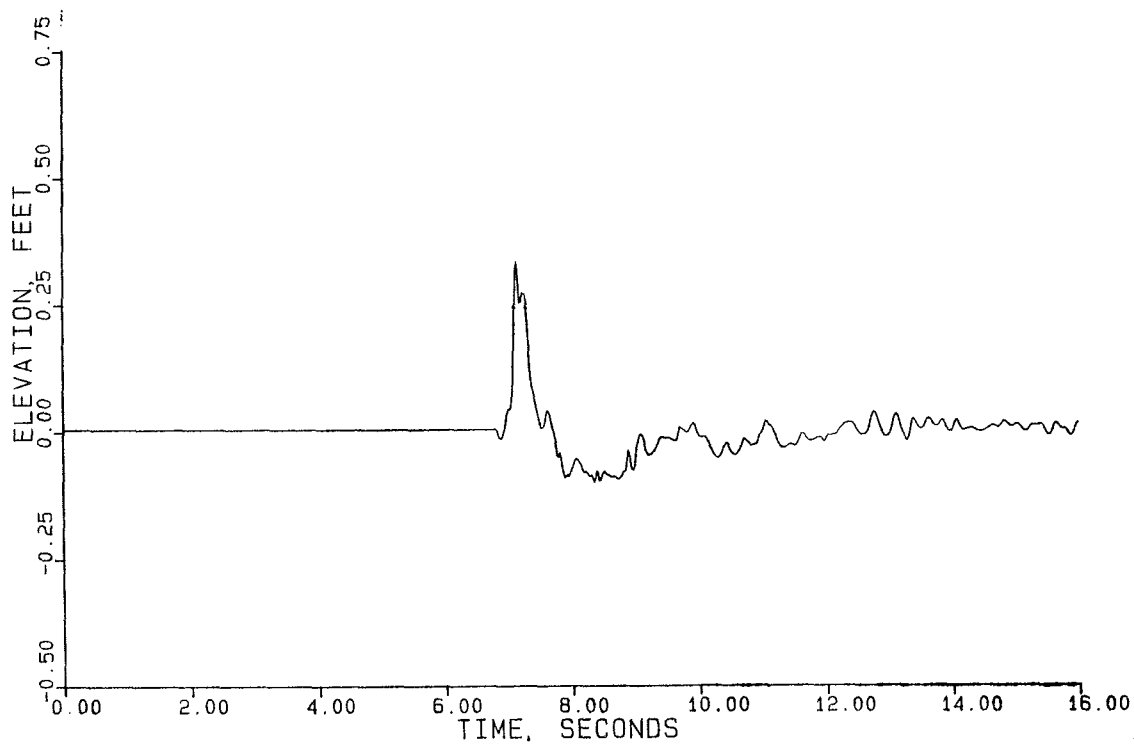
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 25, GAGE 6



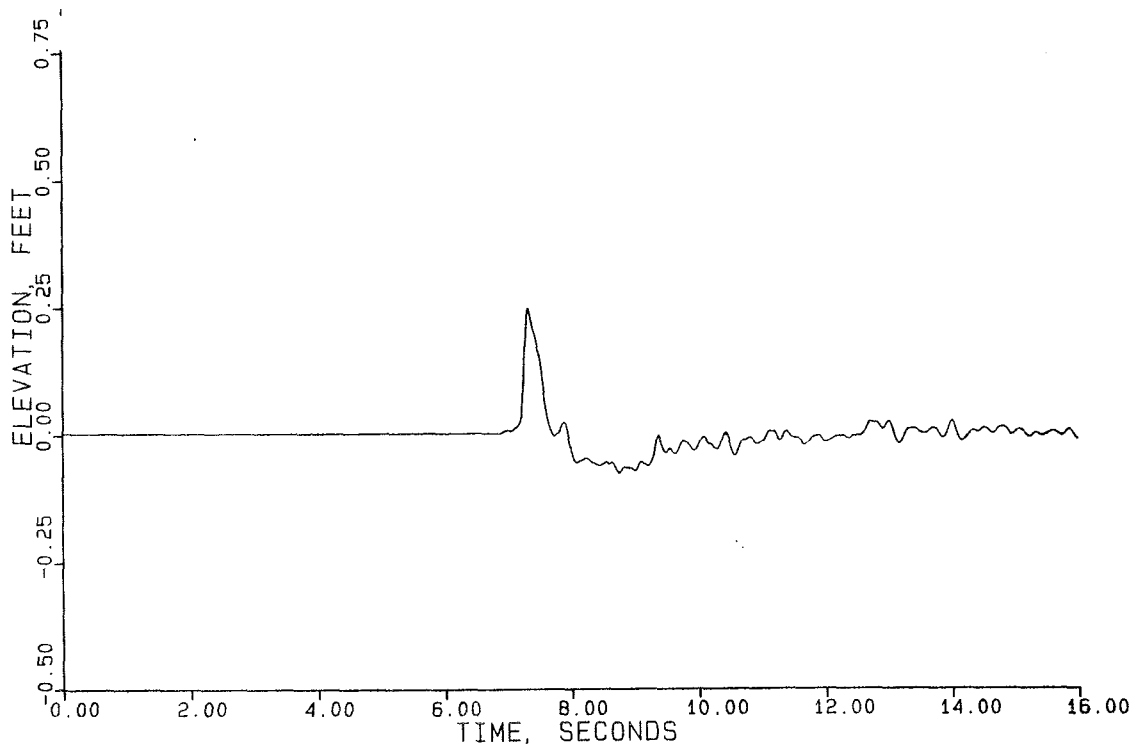
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 1



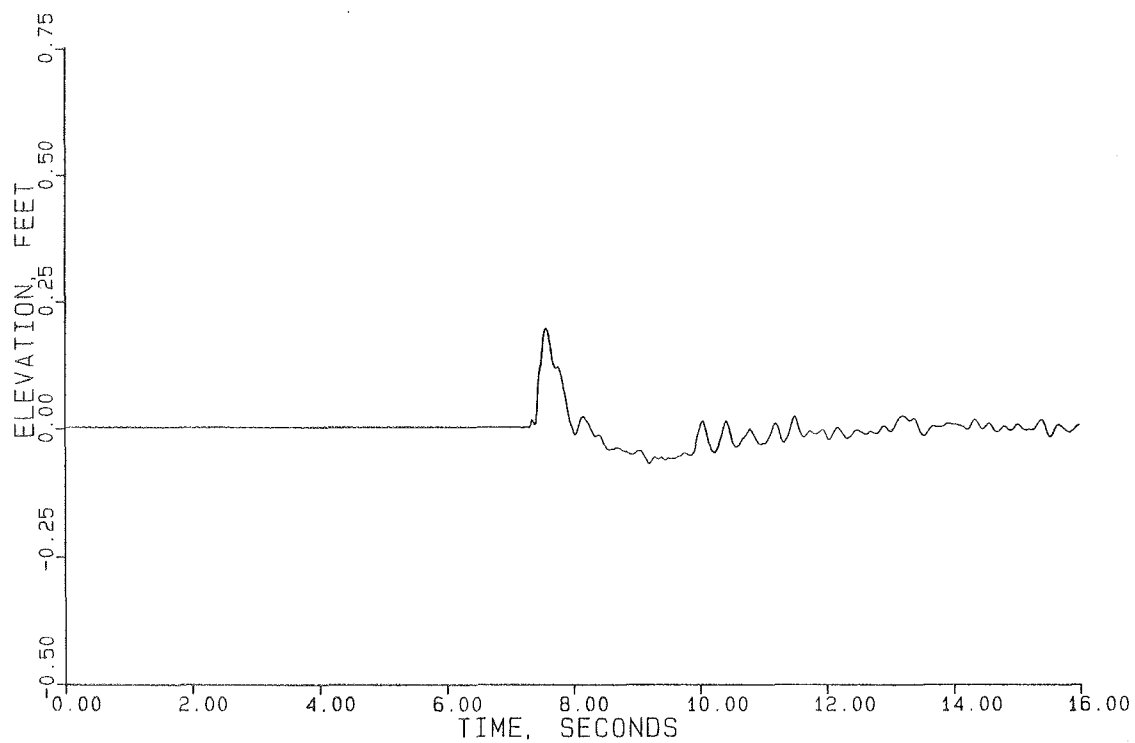
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 2



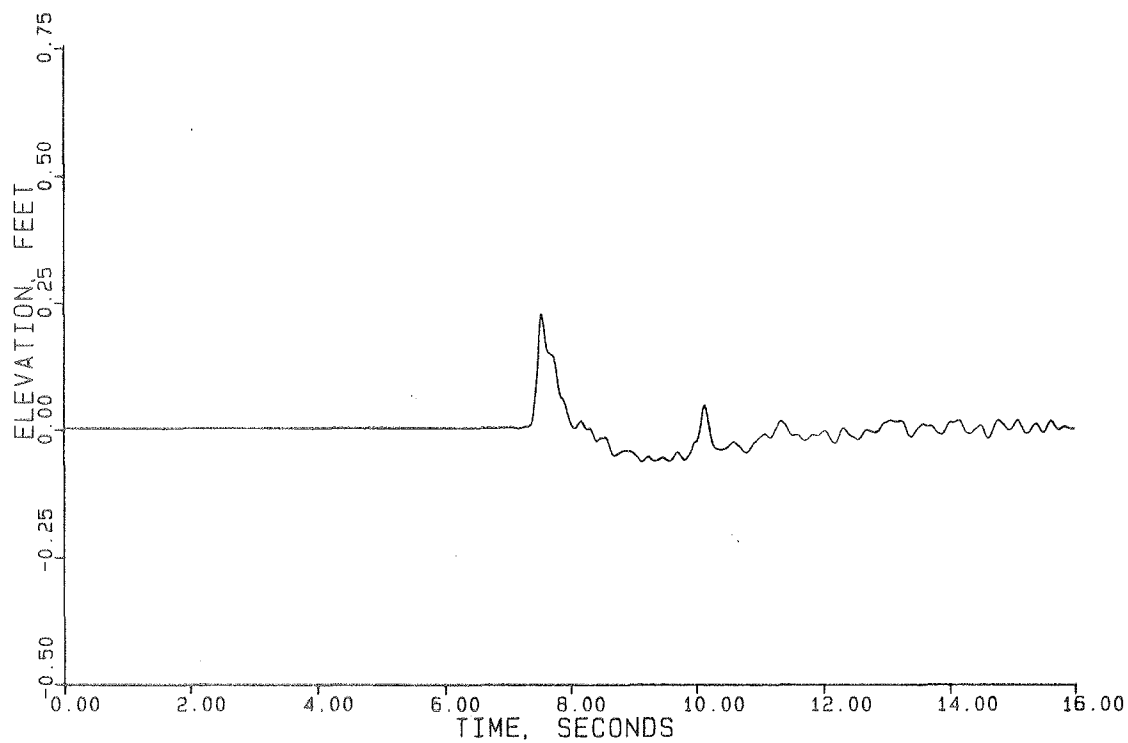
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 2A



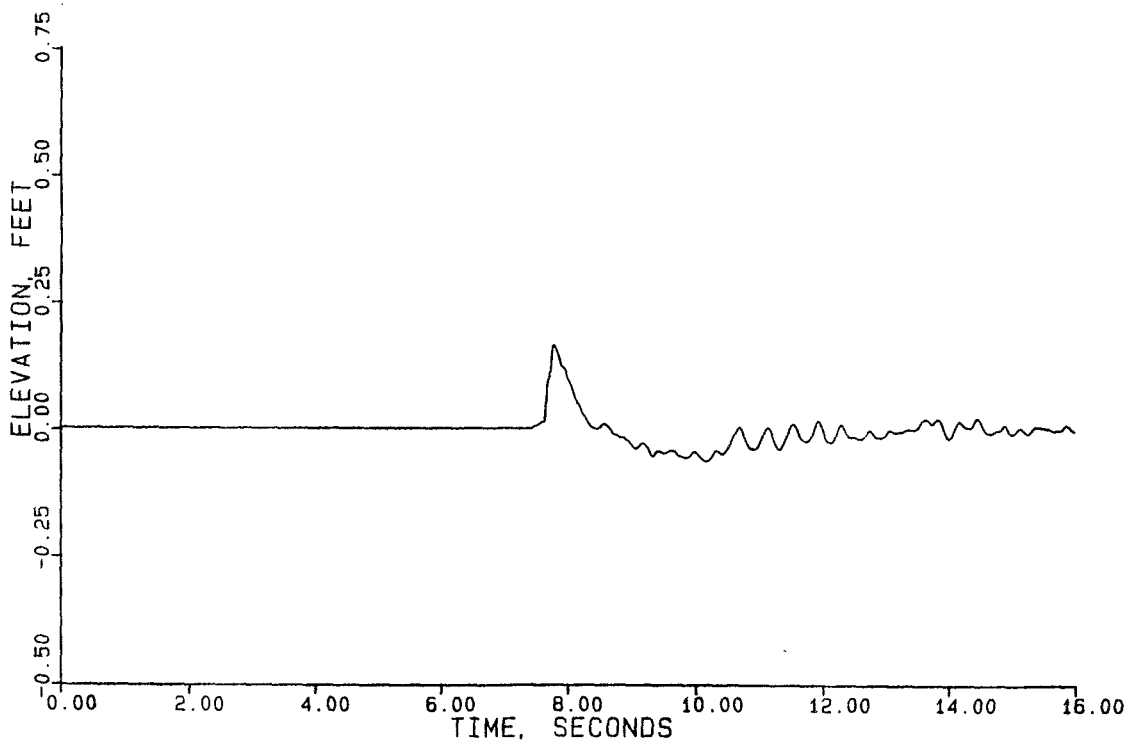
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 3



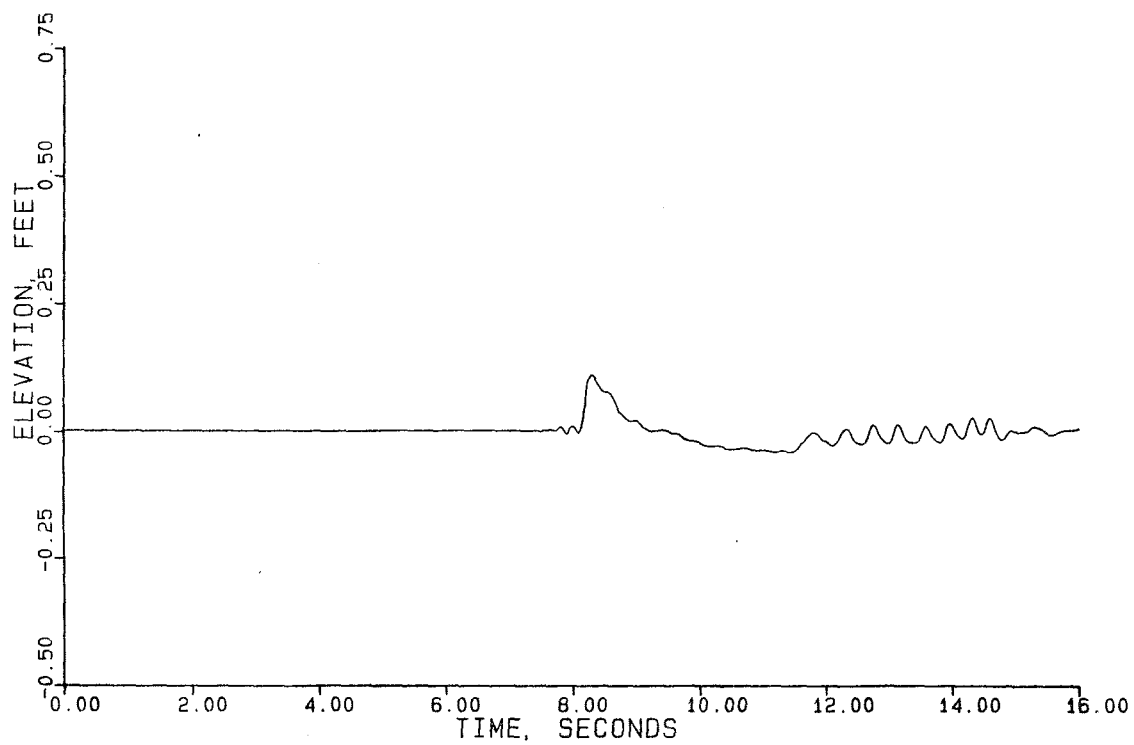
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 4



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 4A



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 5



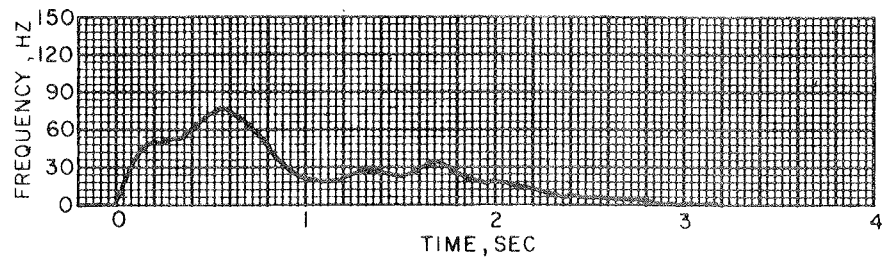
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 26, GAGE 6



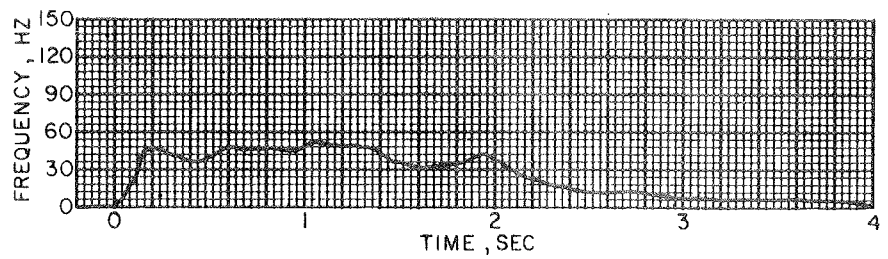
APPENDIX B  
CURRENT MAGNITUDE PLOTS

In this appendix, plots of current magnitude versus time are shown for test conditions in the flat model basin. The flow sensor was positioned 1.25 feet from the edge of the plate for each test. The test number shown on each plot corresponds to the test condition shown in Table 1 in the main body of this report. The instrumentation recorded current magnitude in frequency, hertz, which can be converted to velocity, feet per second, by the calibration curve shown on page 128.

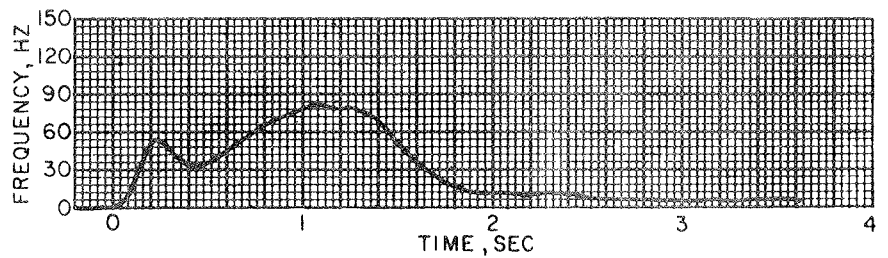
TEST 1



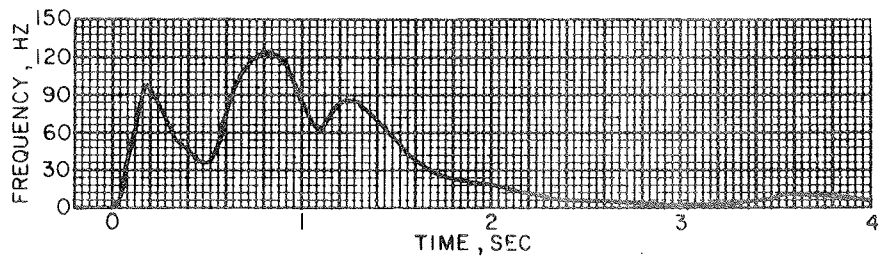
TEST 2



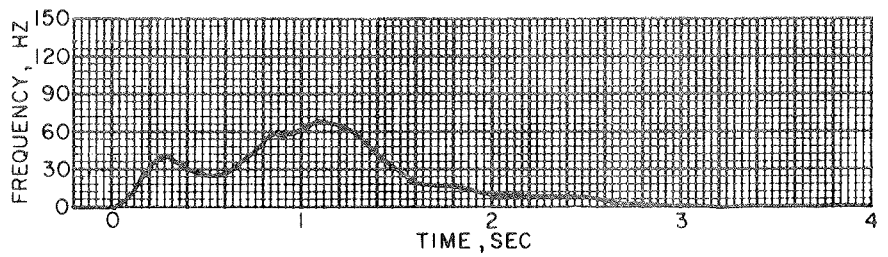
TEST 3



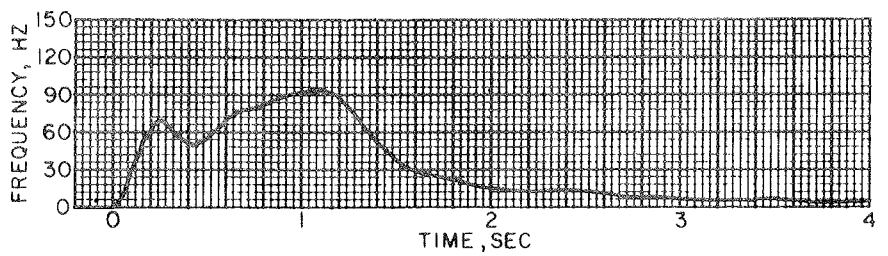
TEST 4



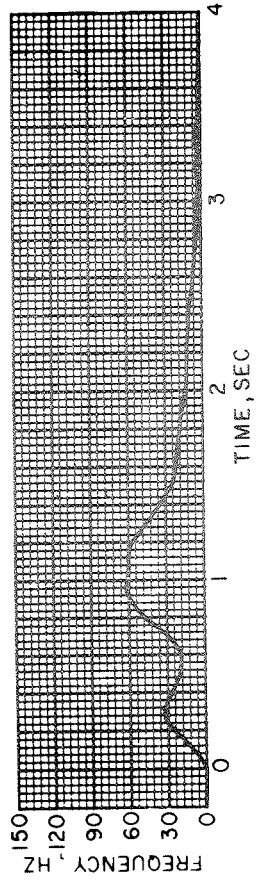
TEST 5



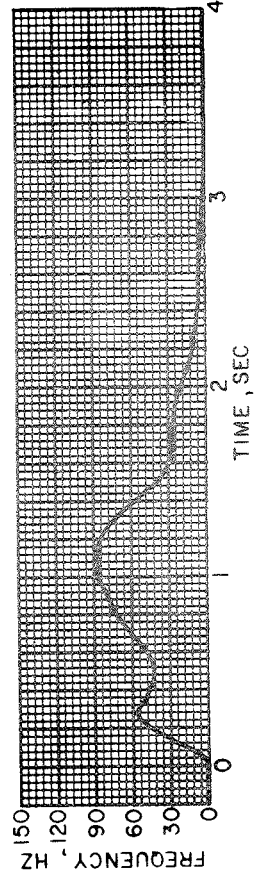
TEST 6



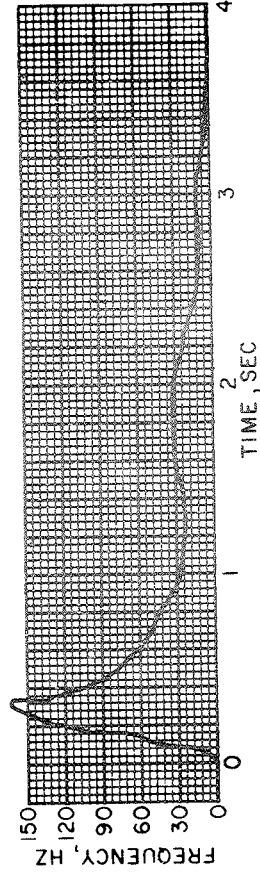
TEST 7



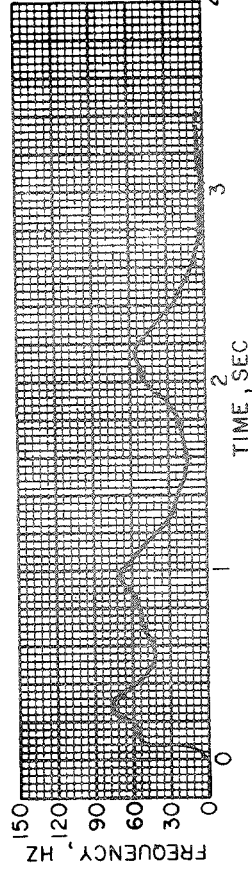
TEST 8



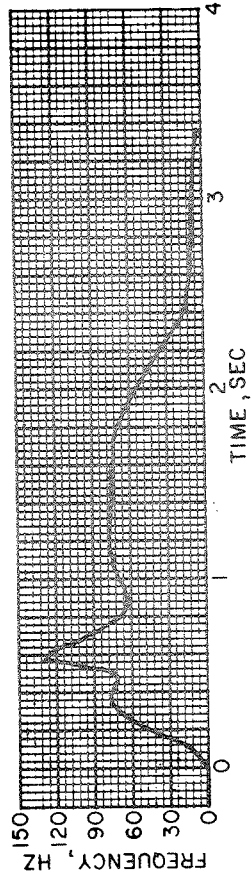
TEST 9



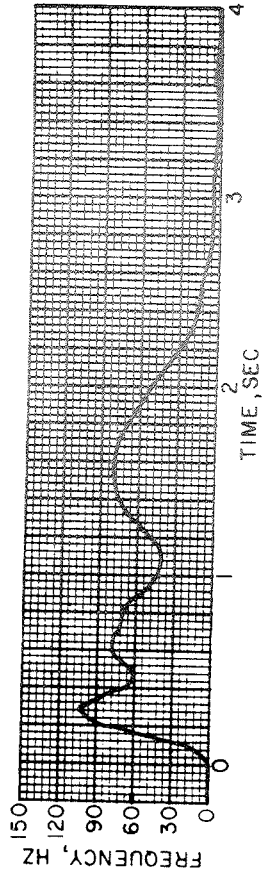
TEST 10



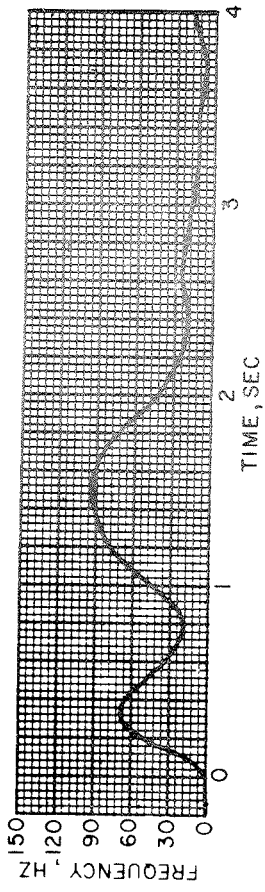
TEST 11



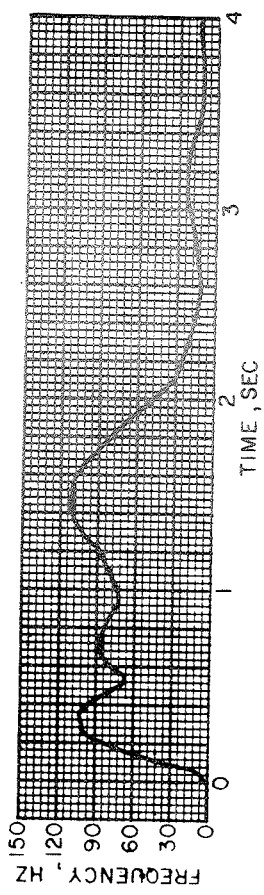
TEST 12



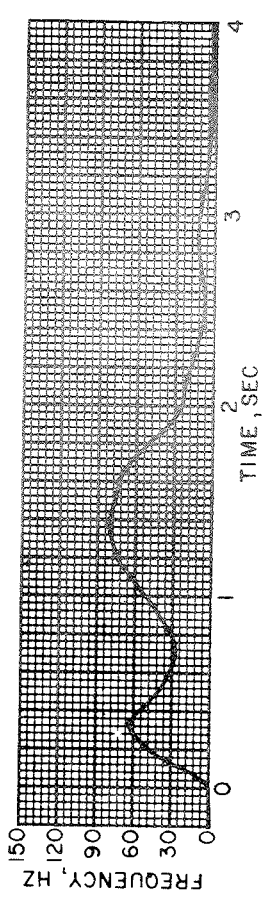
TEST 13



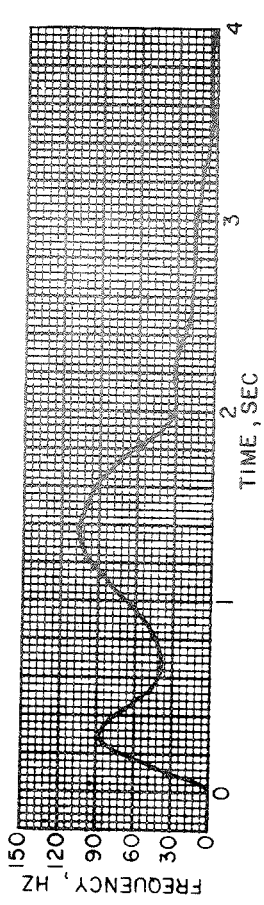
TEST 14



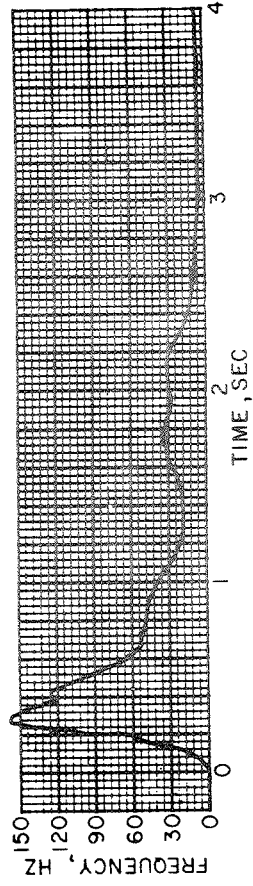
TEST 15



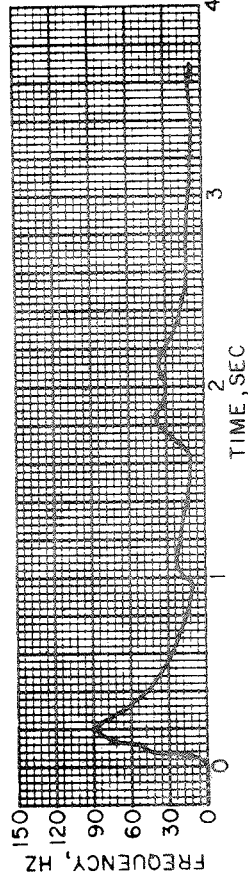
TEST 16



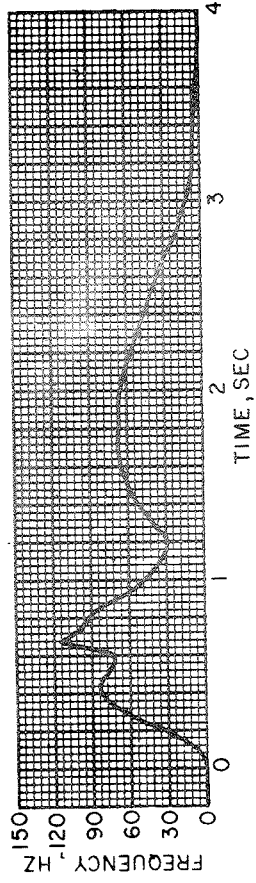
**TEST 17**



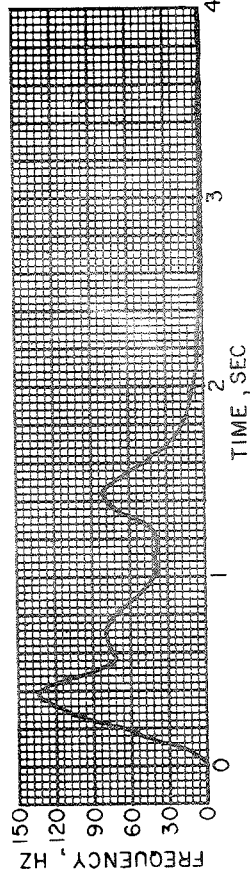
**TEST 18**



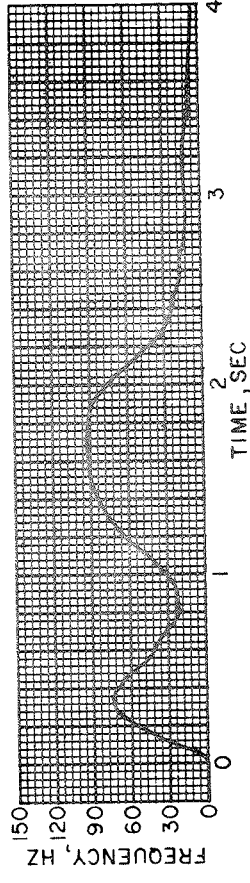
**TEST 19**



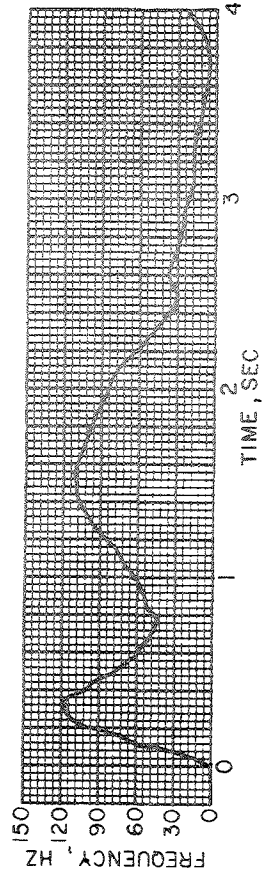
**TEST 20**



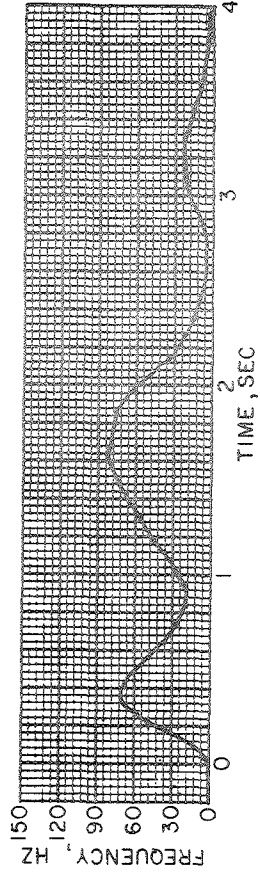
**TEST 21**



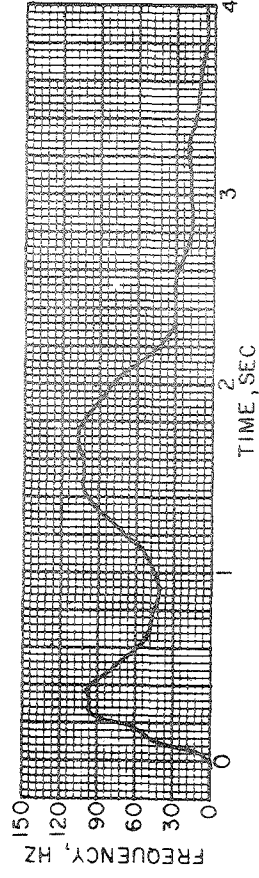
TEST 22



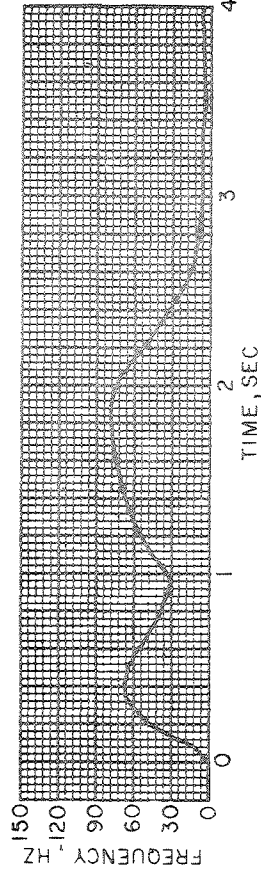
TEST 23



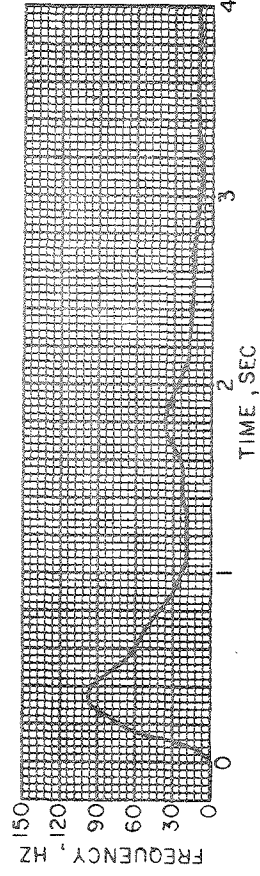
TEST 24

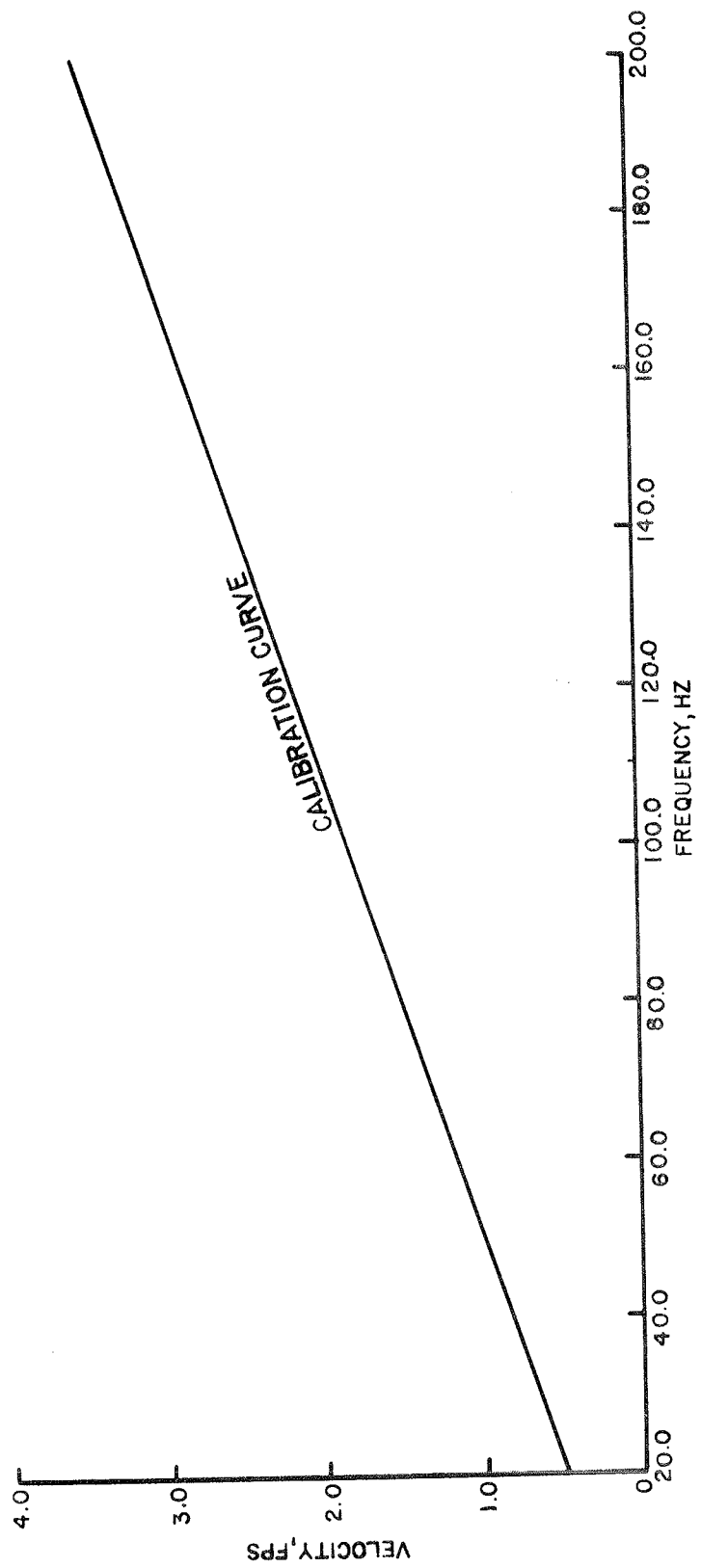


TEST 25



TEST 26





APPENDIX C  
TYPICAL SUBMARINE DISPLACEMENT PHOTOGRAPHS

Selected photographs depicting small-scale model submarine displacement in the flat model basin resulting from impulsive waves are shown in this appendix. Test numbers associated with each series of photographs correspond to the test conditions shown in Table 1 in the main body of this report.





a

b

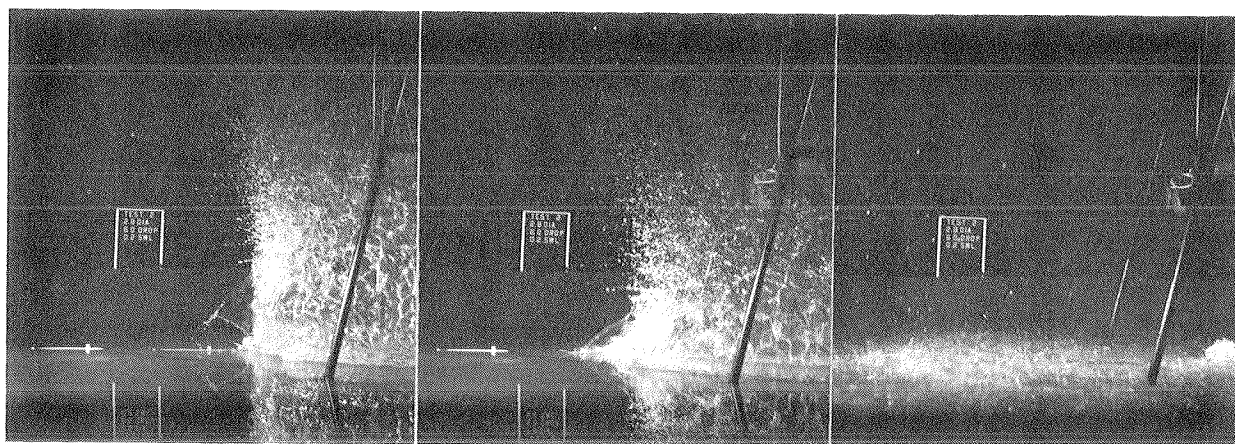
c



d

e

f

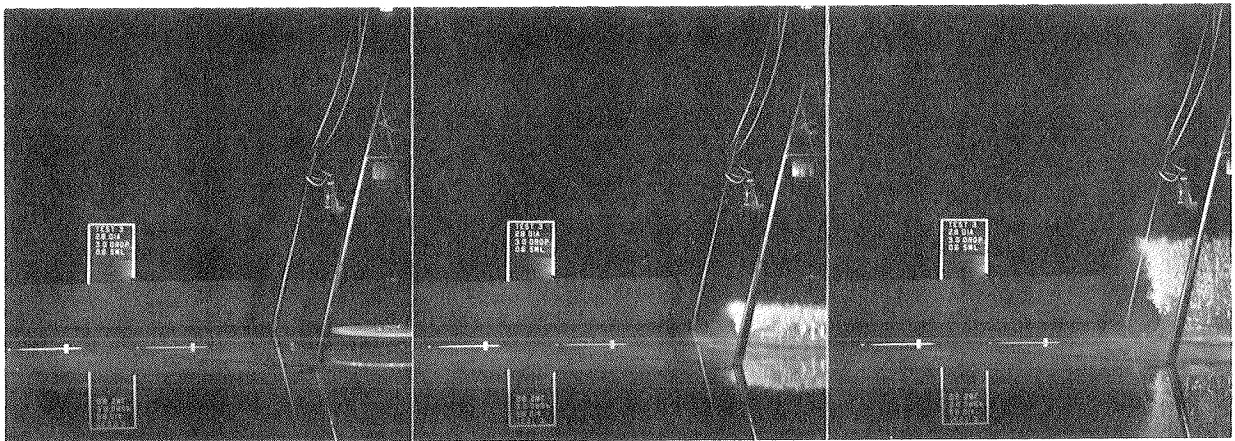


g

h

i

TEST 2



a

b

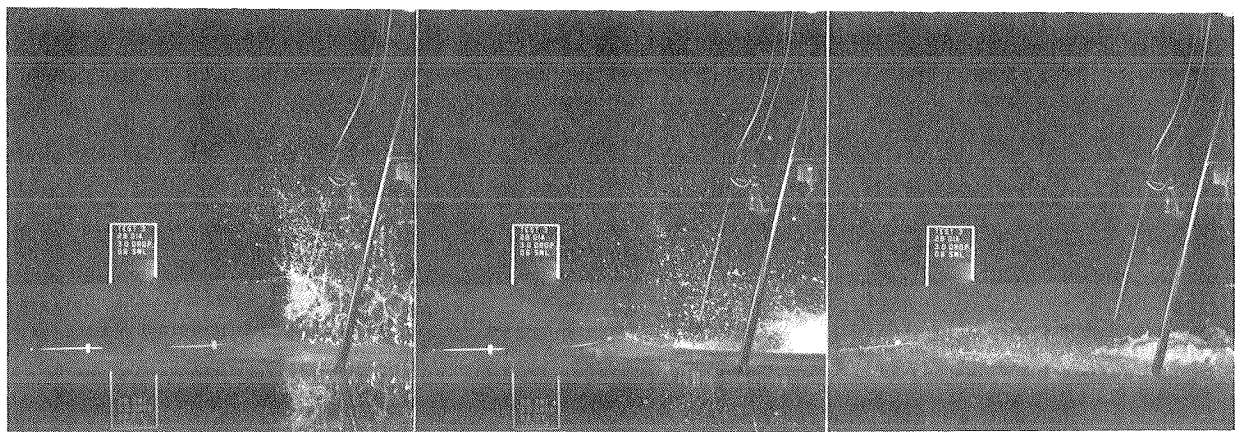
c



d

e

f



g

h

i

TEST 3

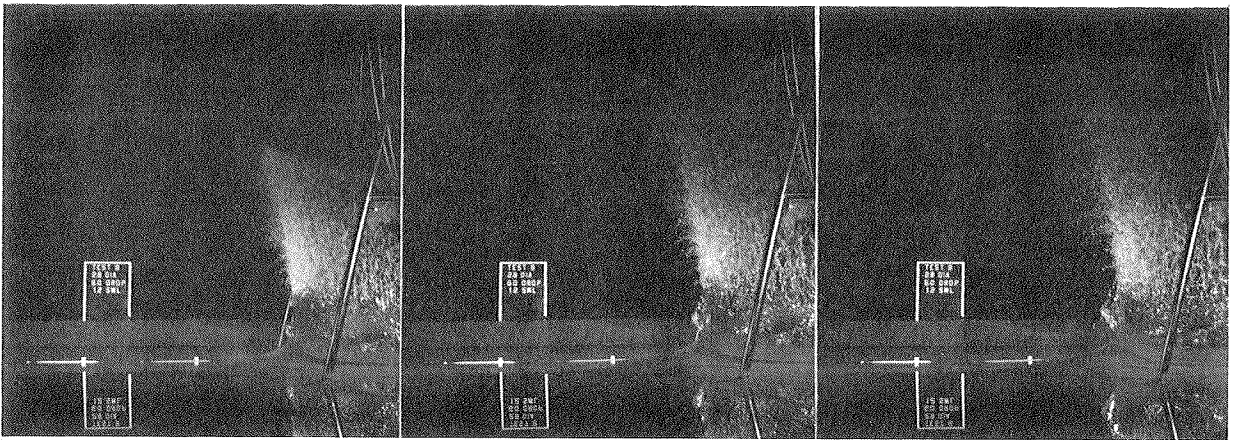




a

b

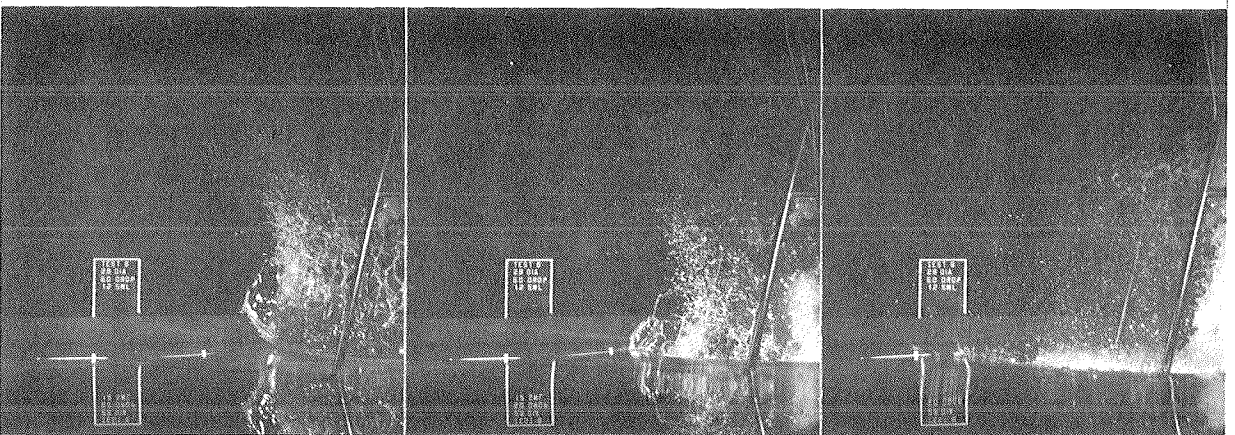
c



d

e

f

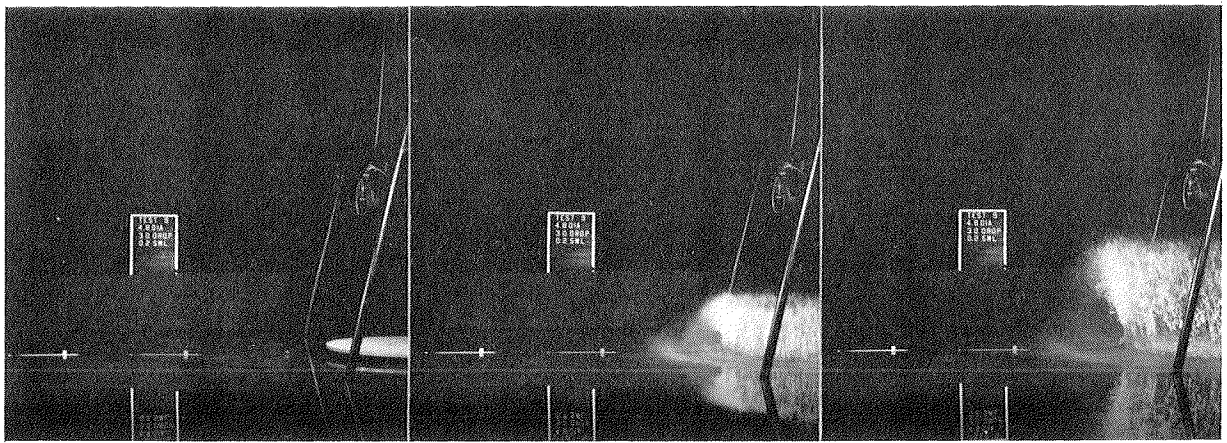


g

h

i

TEST 8



a

b

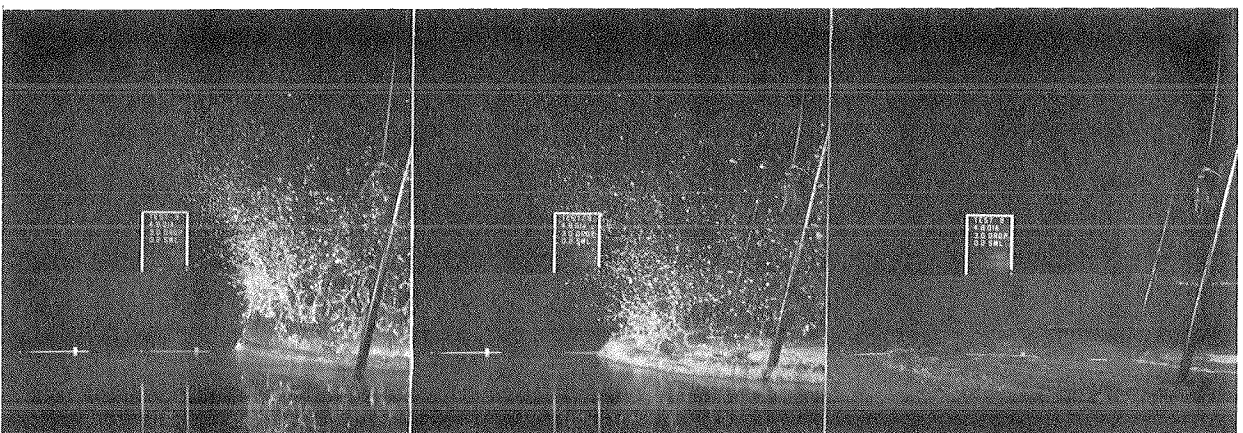
c



d

e

f



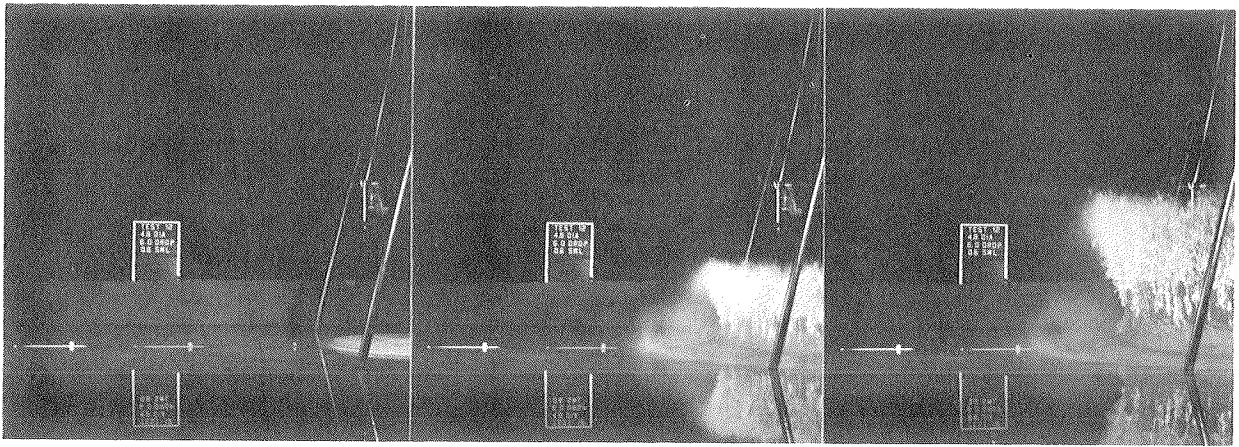
g

h

i

TEST 9





a

b

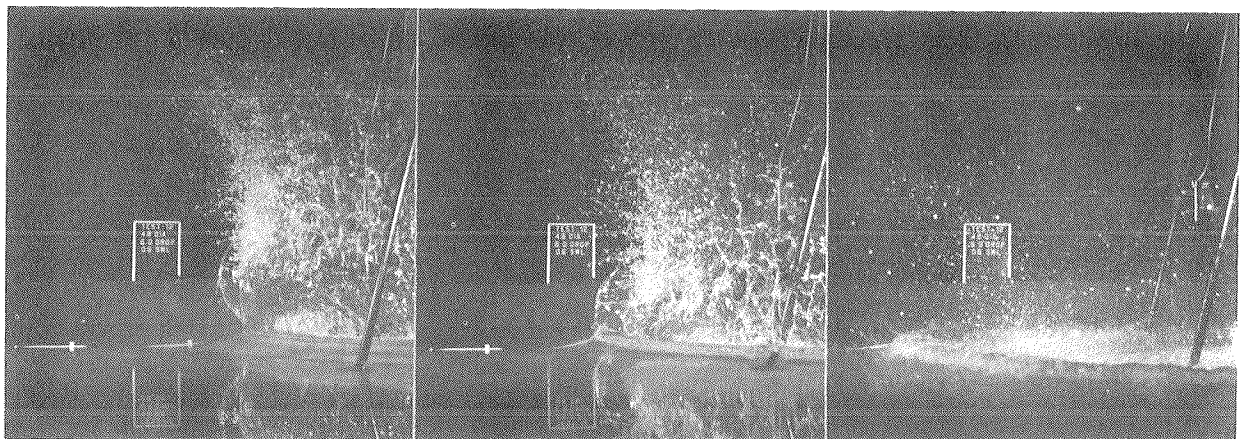
c



d

e

f

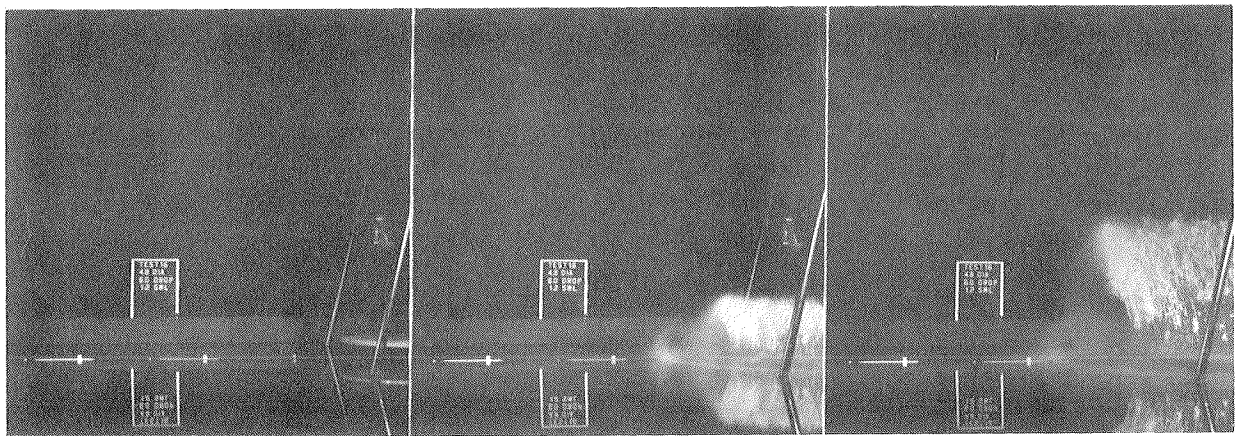


g

h

i

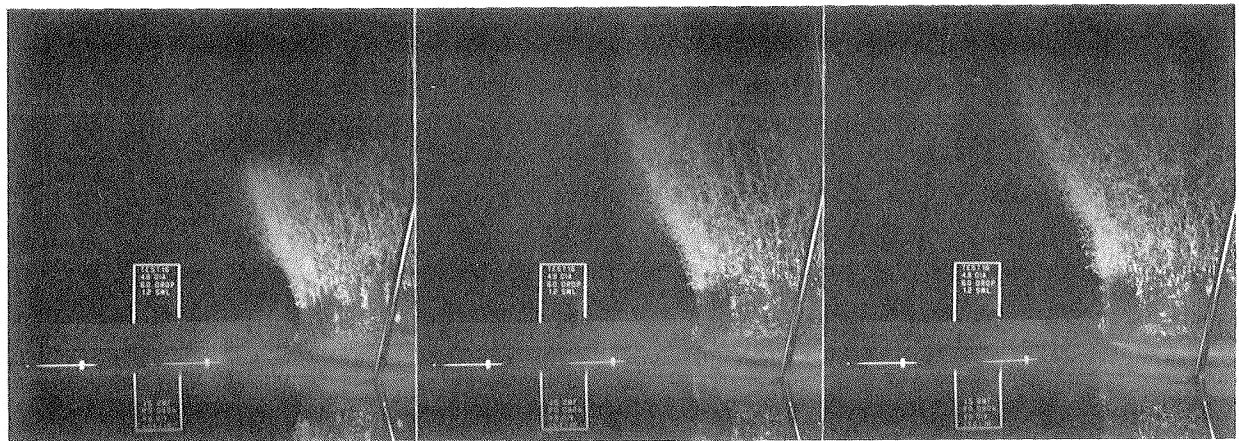
TEST 12



a

b

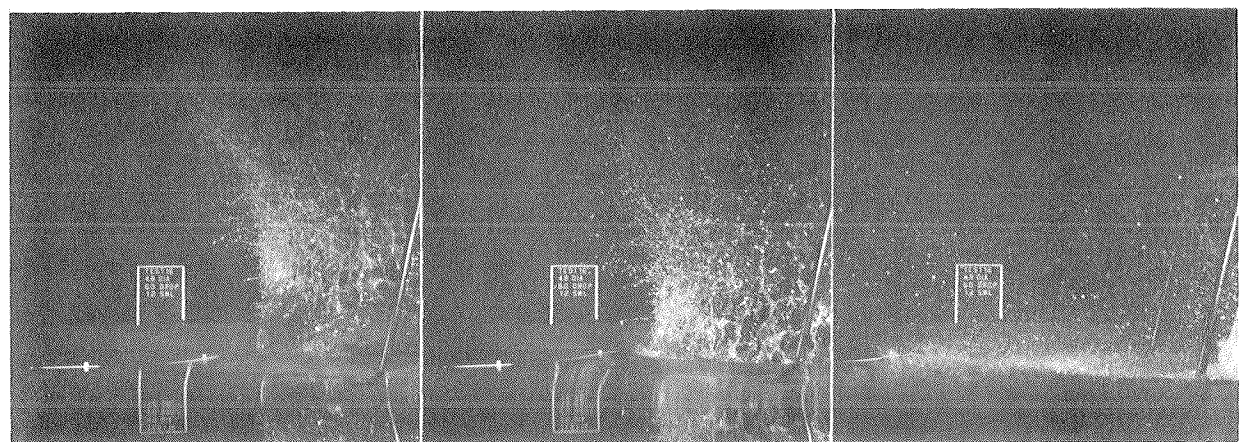
c



d

e

f



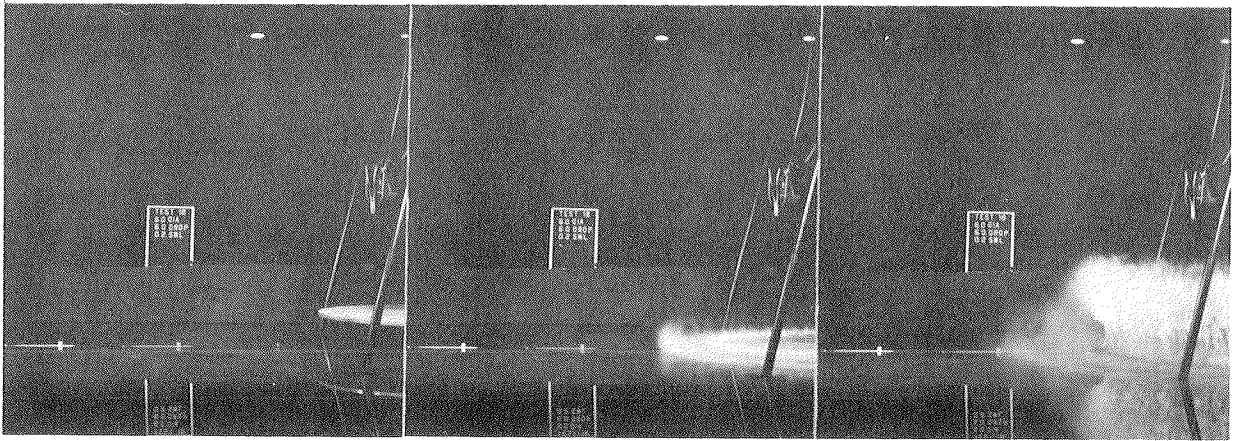
g

h

i

TEST 16

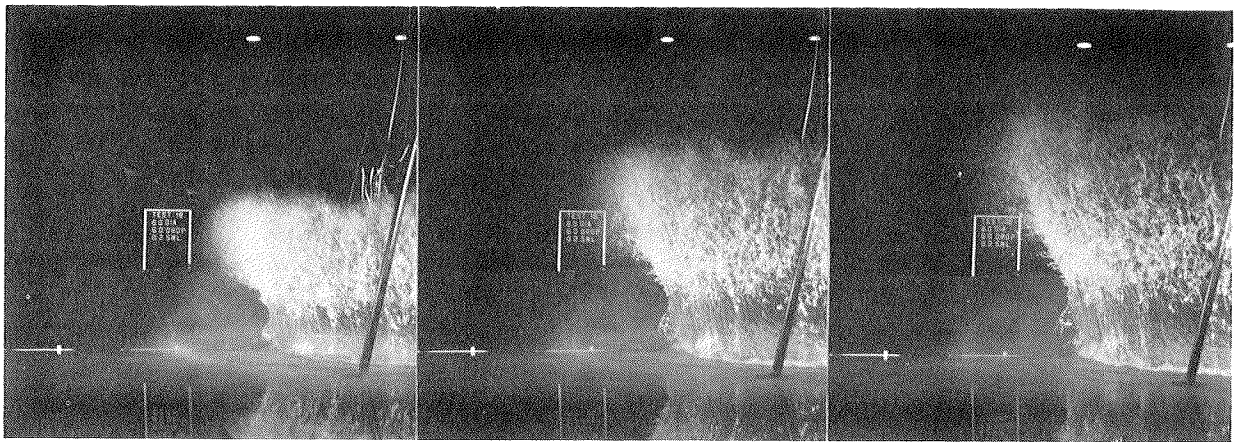




a

b

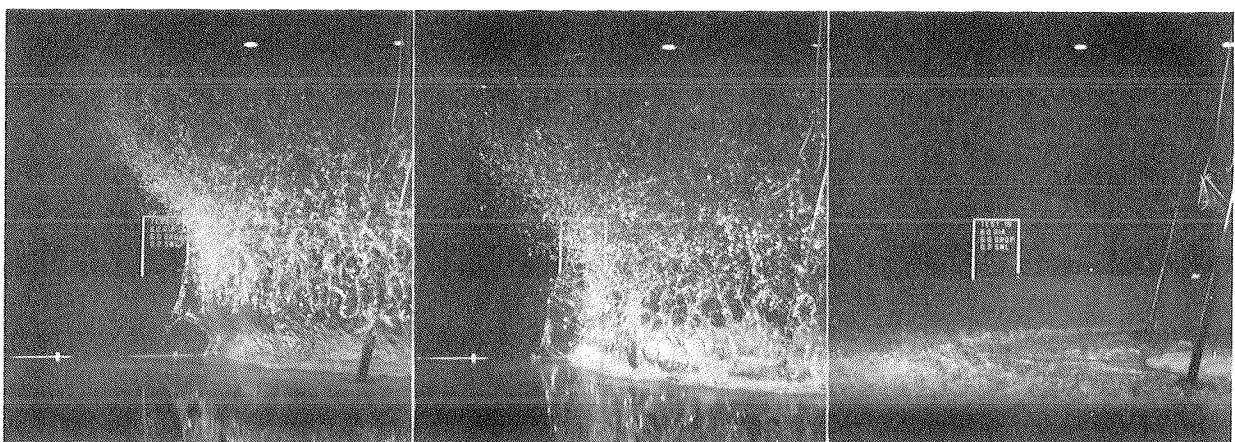
c



d

e

f

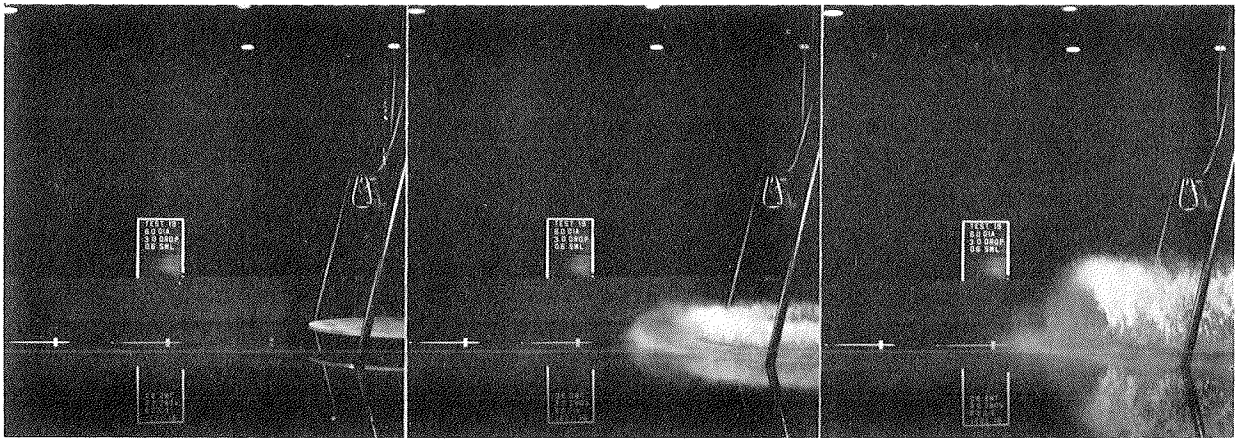


g

h

i

TEST 18



a

b

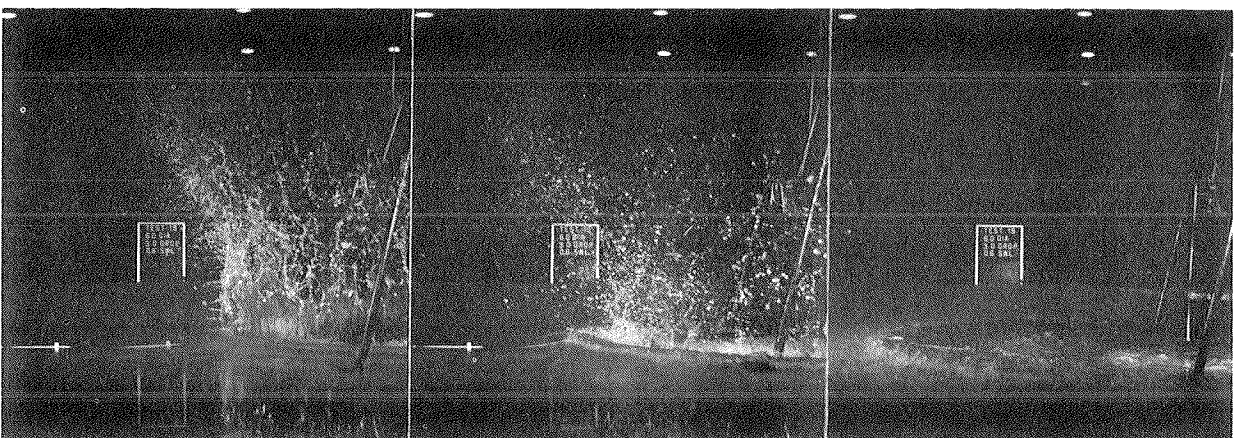
c



d

e

f



g

h

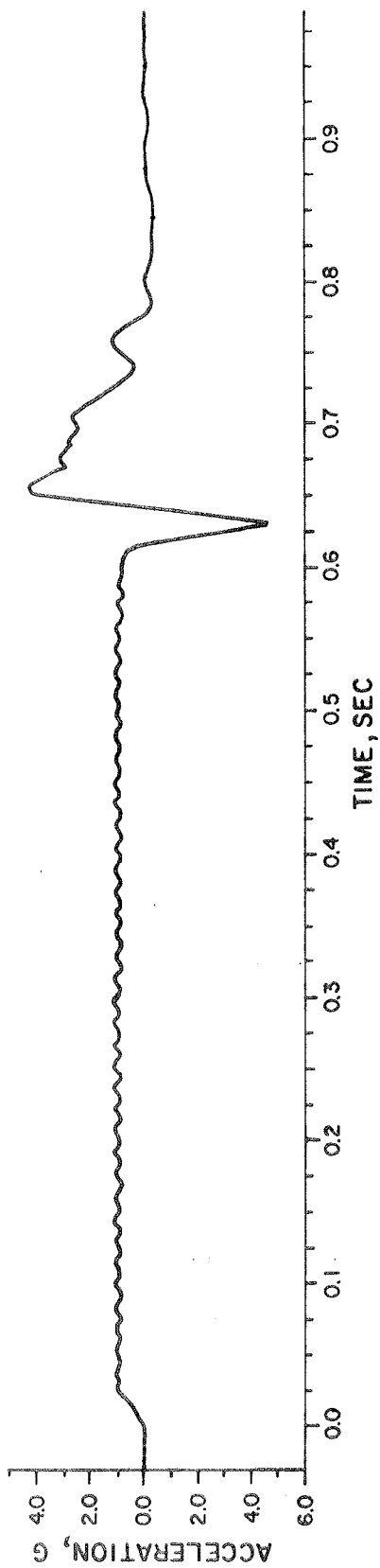
i

TEST 19

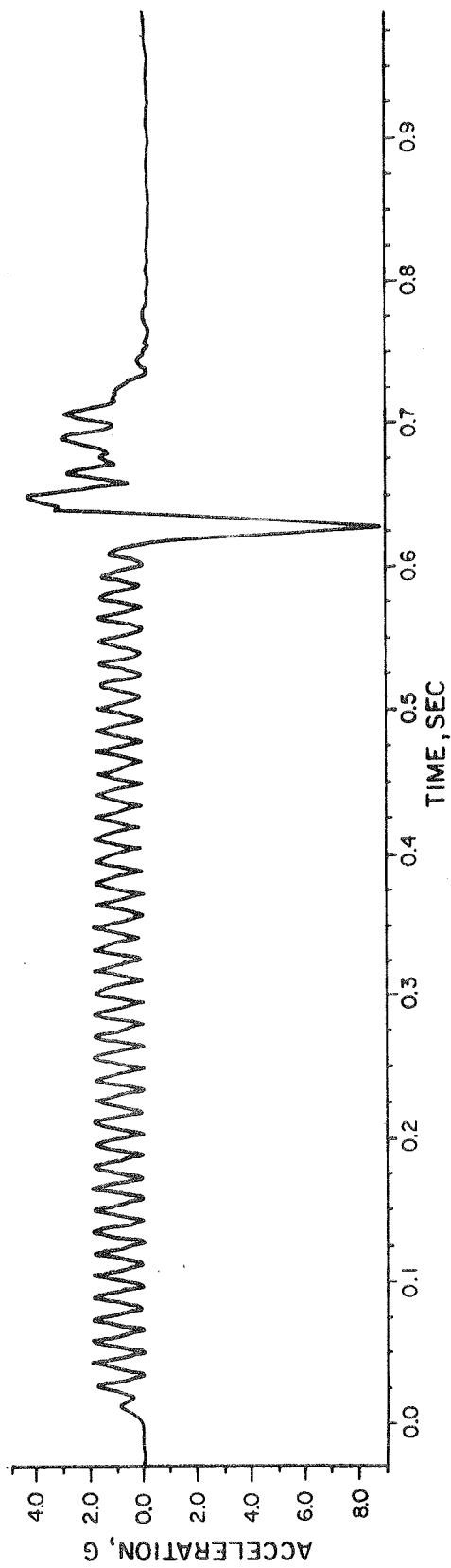


APPENDIX D  
ACCELERATION DATA

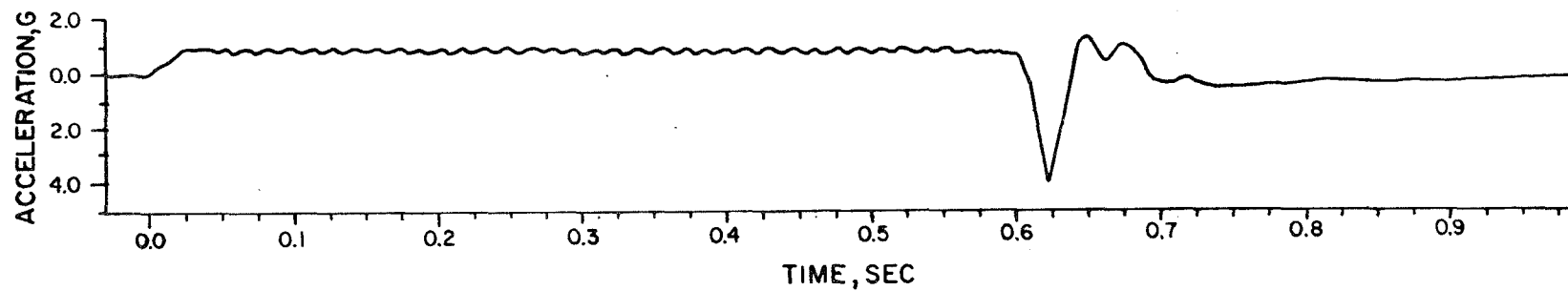
Acceleration data recorded for the steel discs for various test conditions are presented in this appendix. Acceleration due to gravity was measured in the vertical direction. The test number shown on each plot corresponds to test conditions shown in Table 1 in the main body of this report.



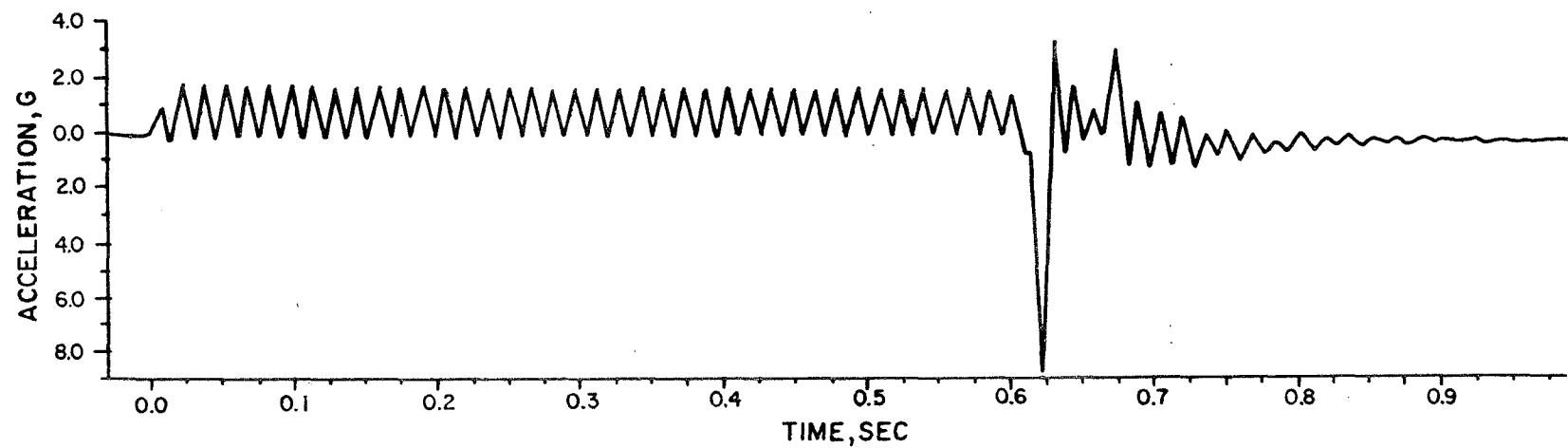
TEST 18 (25 Hz Lowpass Filter)



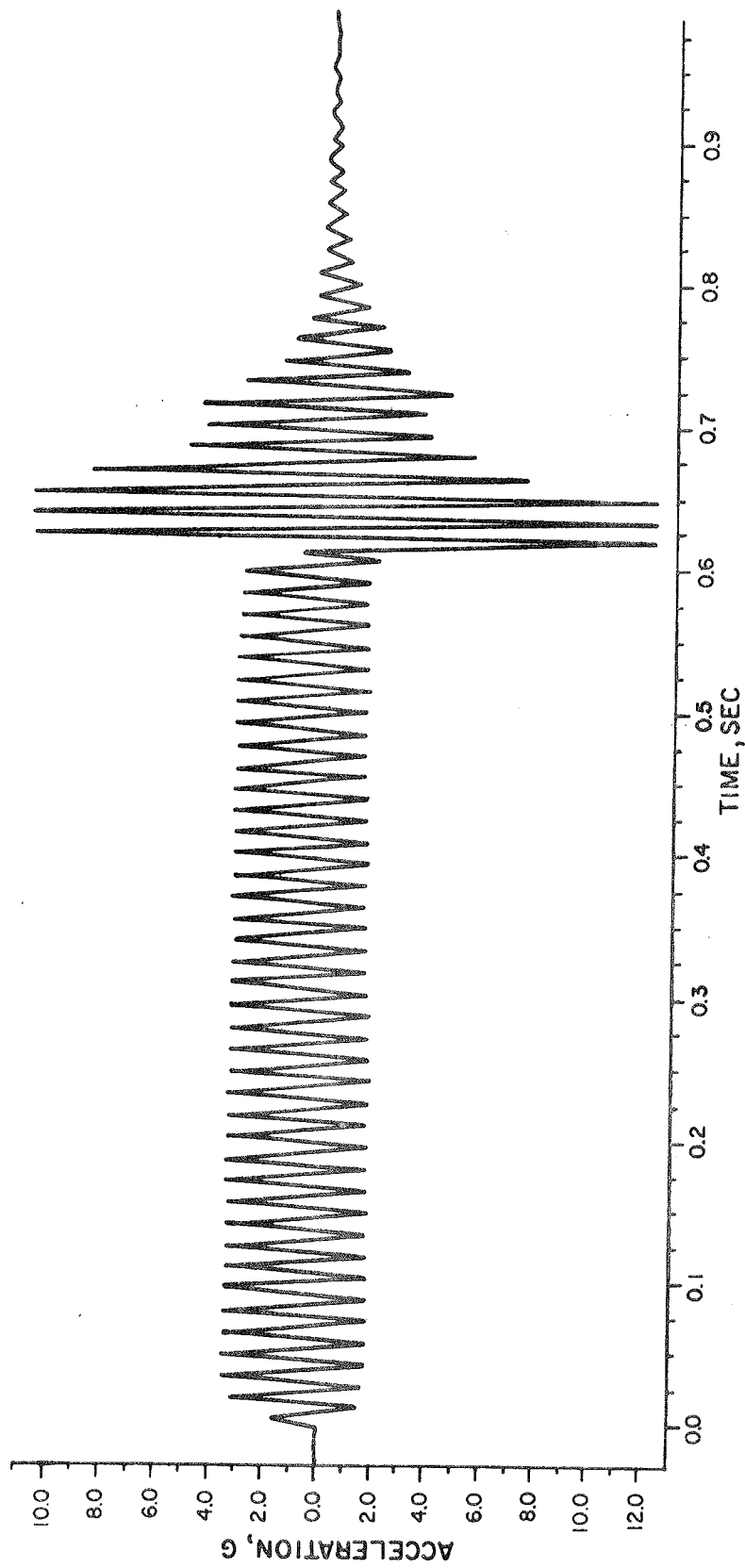
TEST 18 (50 Hz Lowpass Filter)



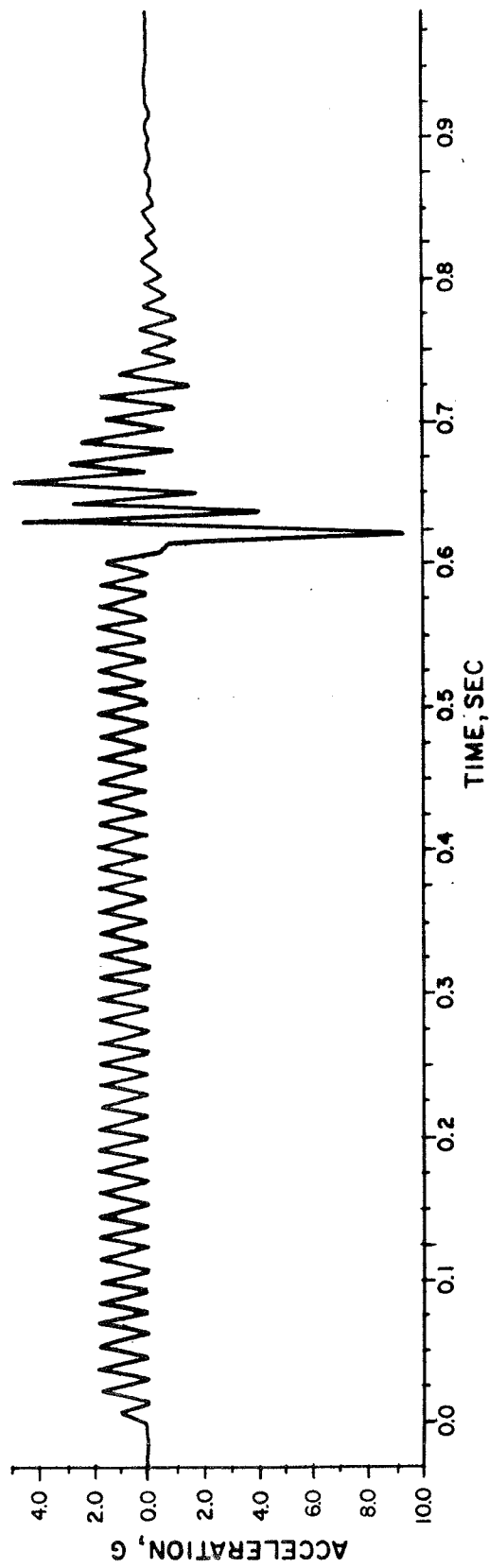
TEST 22 (25 Hz Lowpass Filter)



TEST 22 (50 Hz Lowpass Filter)



TEST 24 (100 Hz Lowpass Filter)

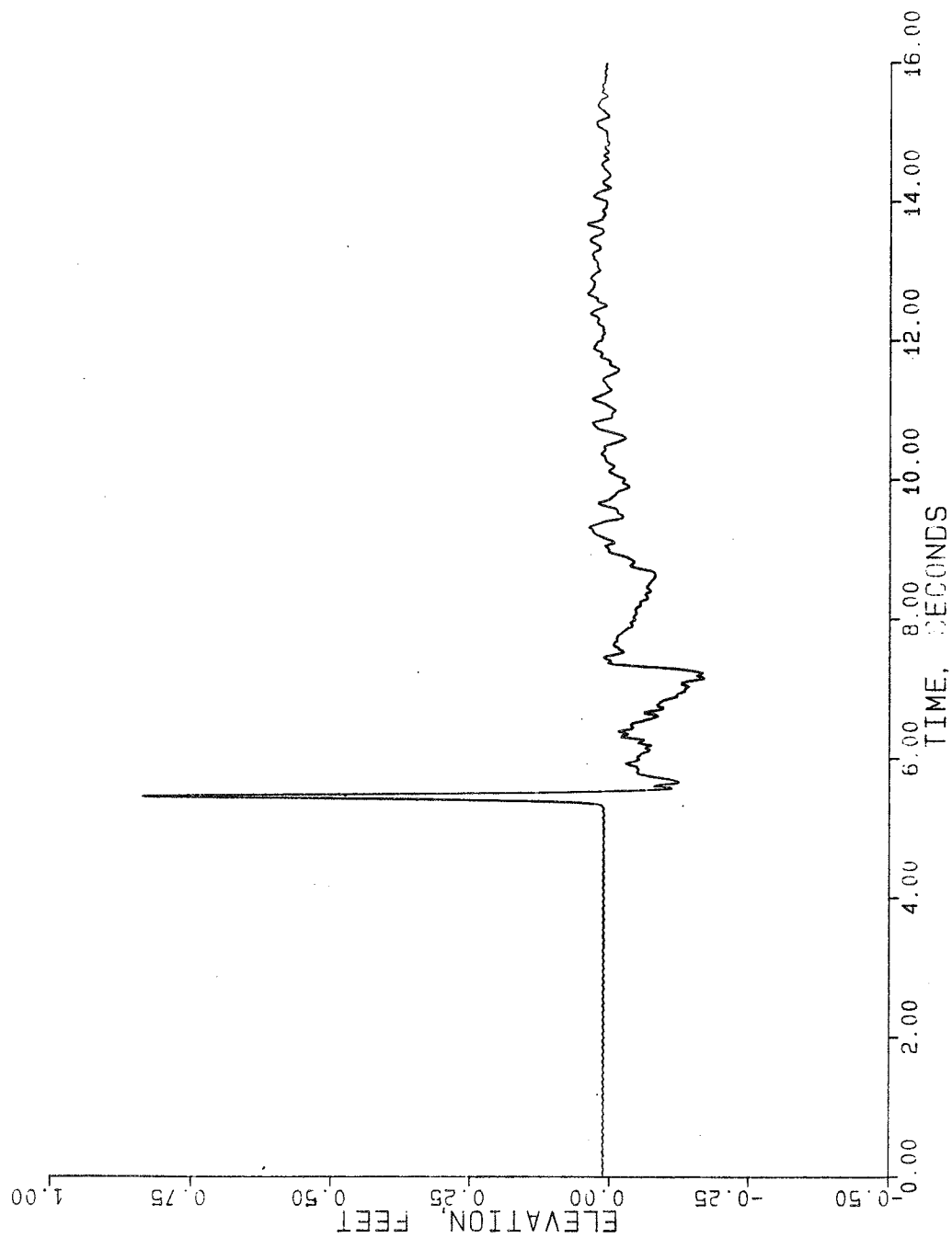


TEST 24 (50 Hz Lowpass Filter)

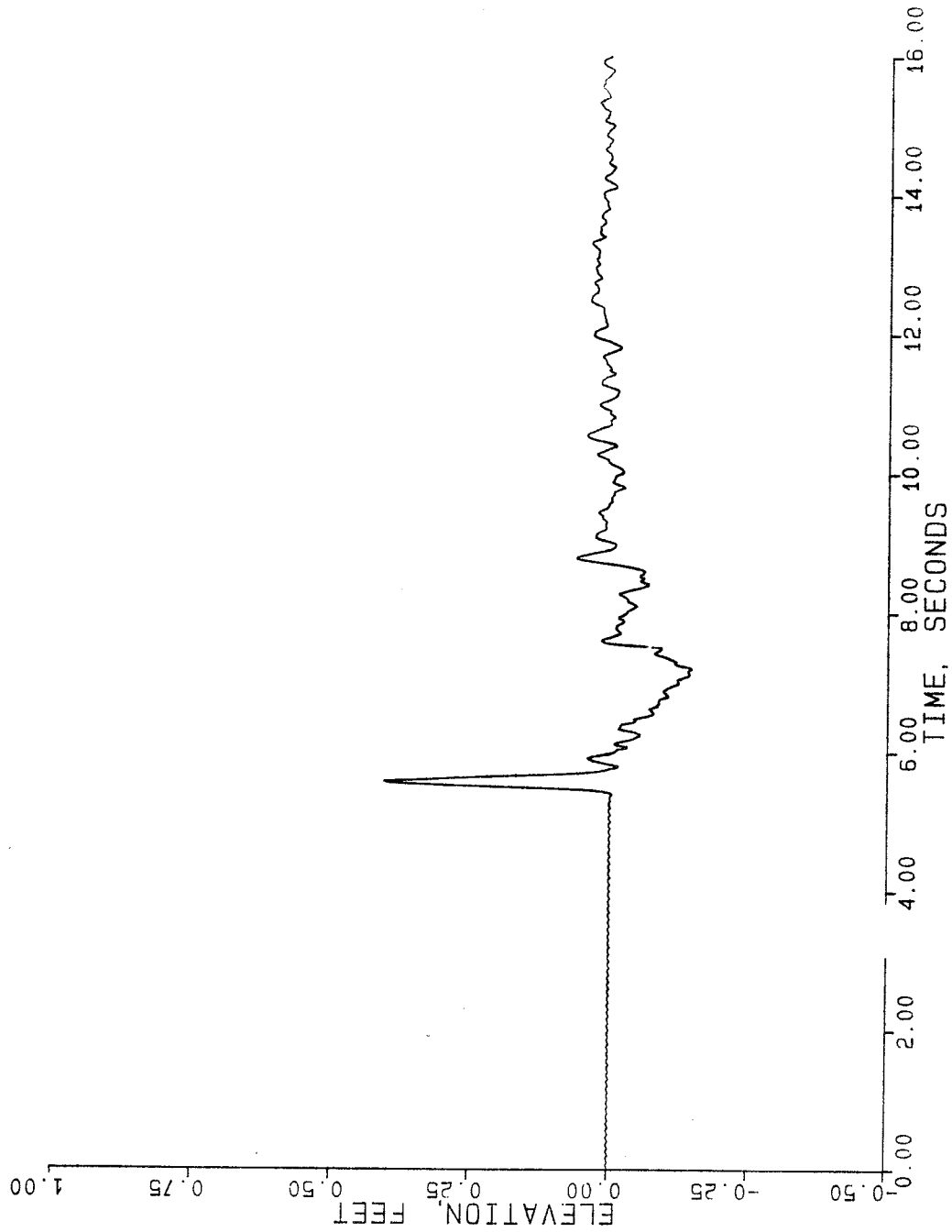
## APPENDIX E

### WAVE TRAIN TIME-HISTORIES OBTAINED IN GENERALIZED INLET MODEL

Wave train time-histories obtained in the generalized inlet model are presented in this appendix. The test number shown on each plot corresponds to test conditions shown in Table 1 in the main body of this report. Gage numbers also are identified on each figure.

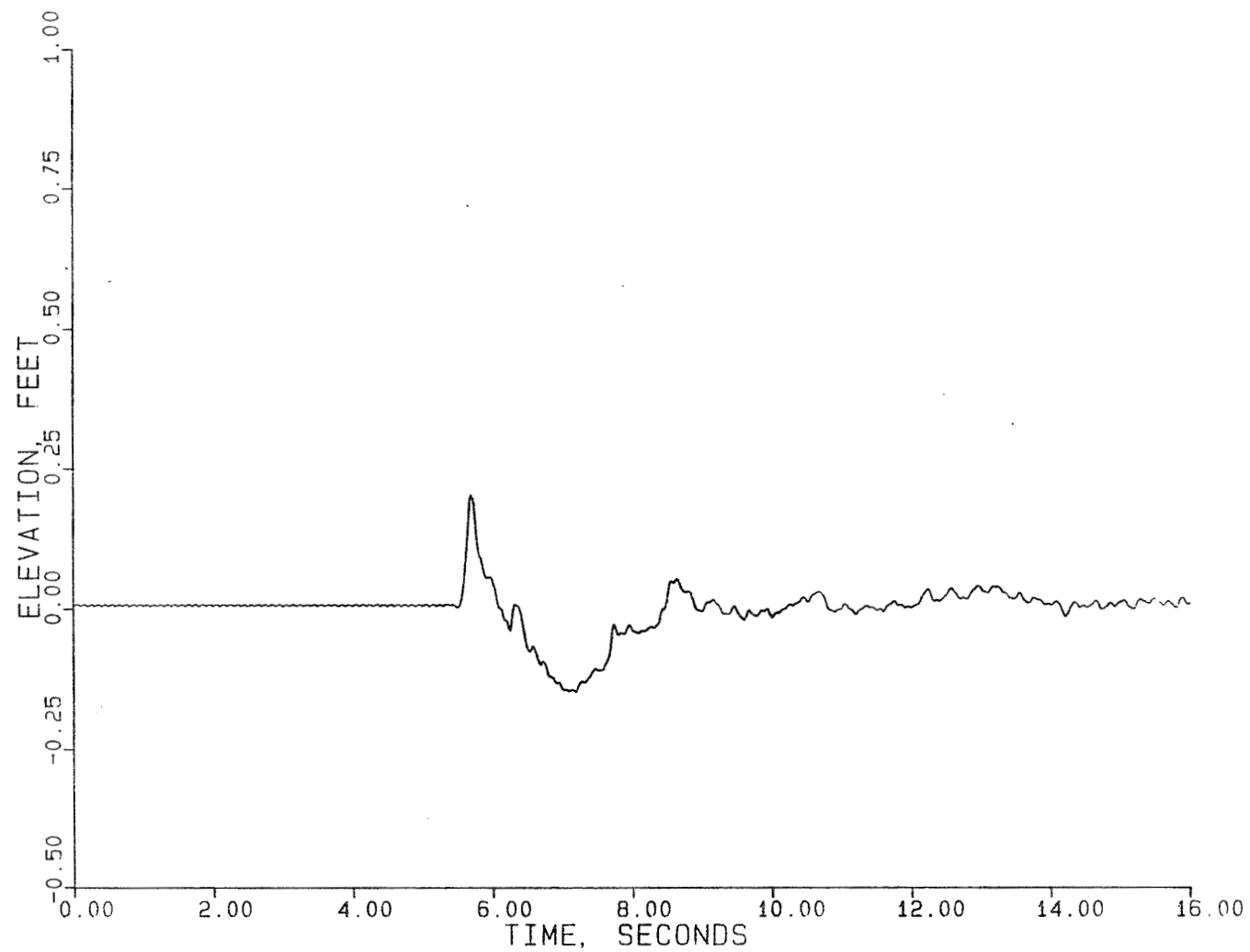


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 27, GAGE 1

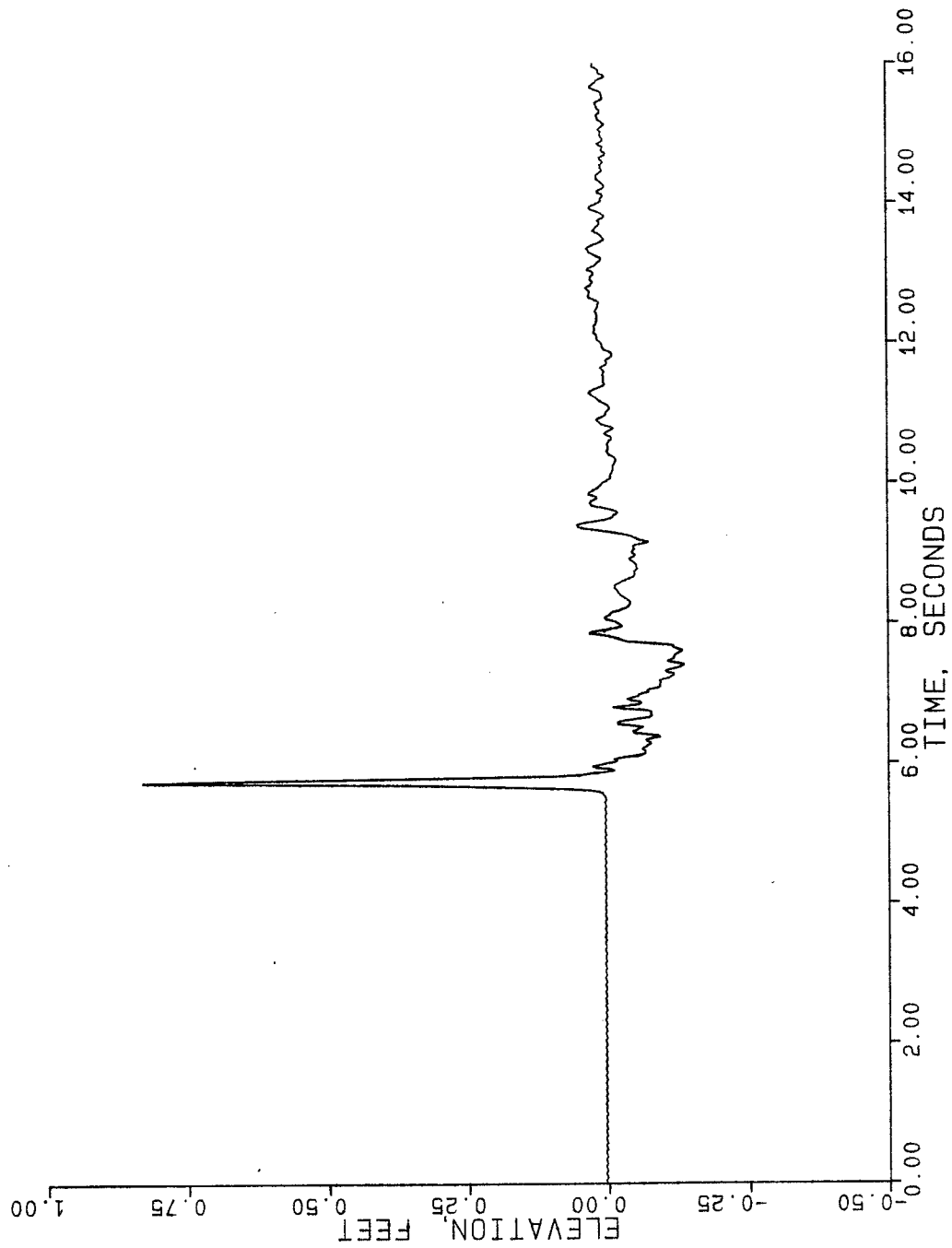


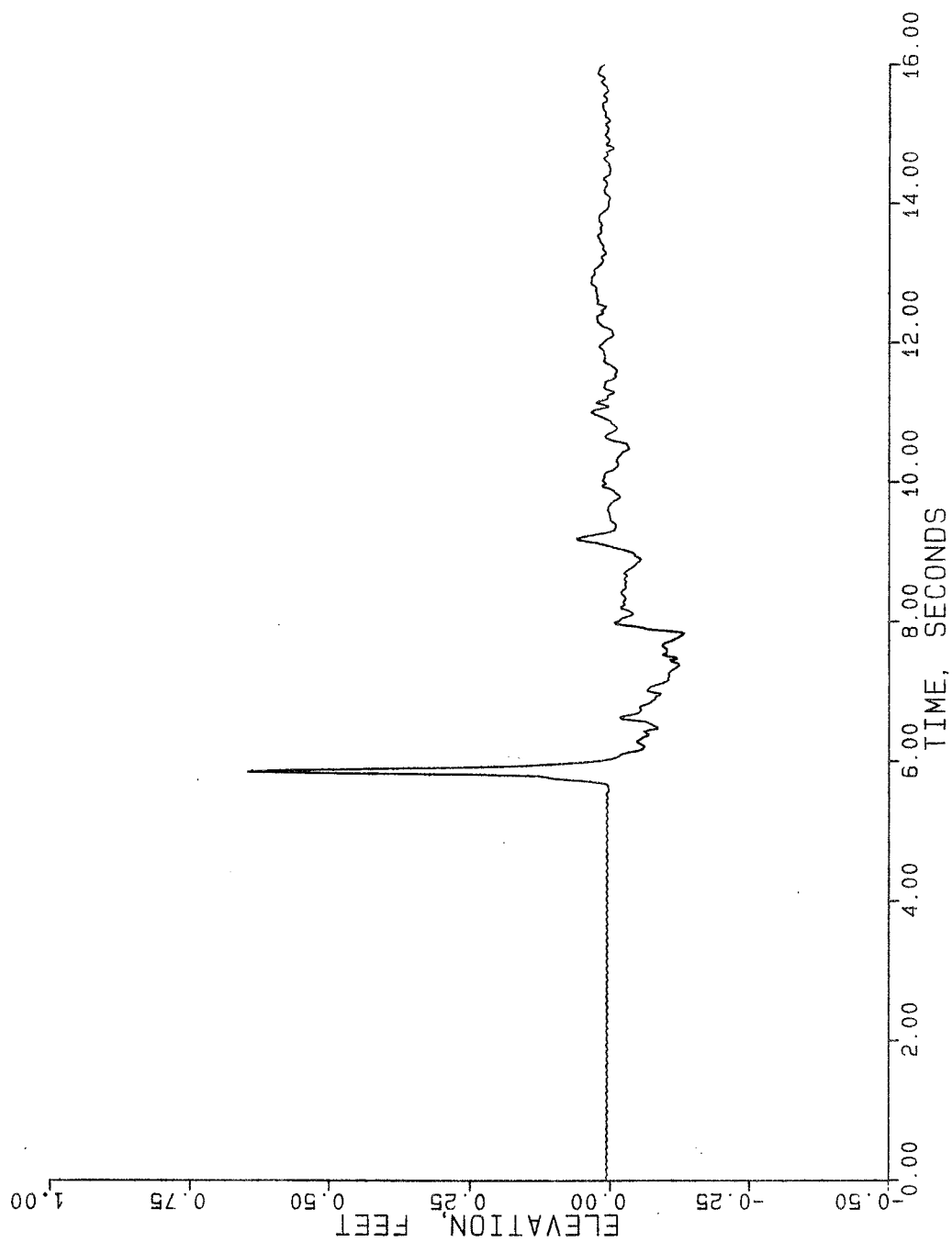
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 27, GAGE 2



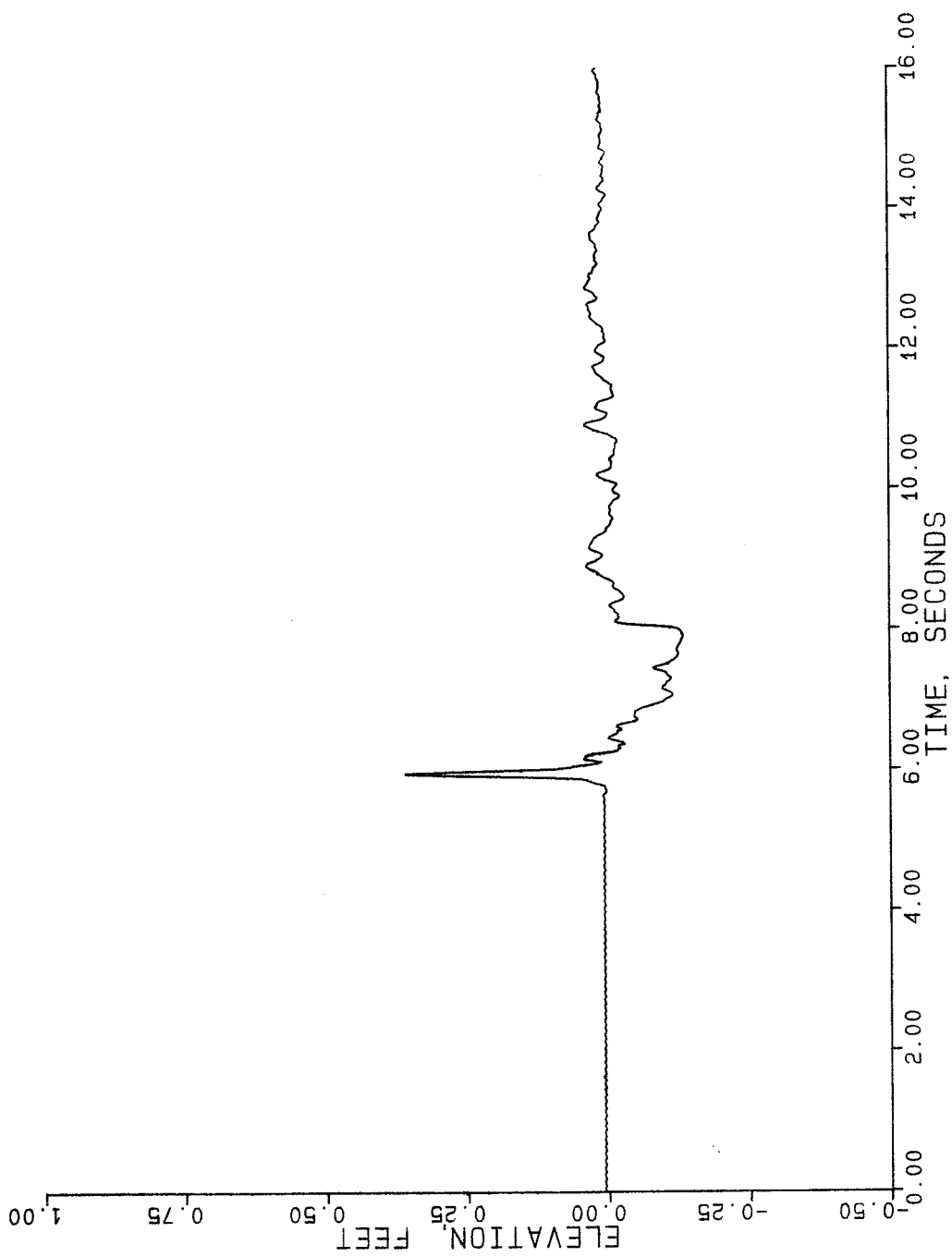


WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 27, GAGE 3

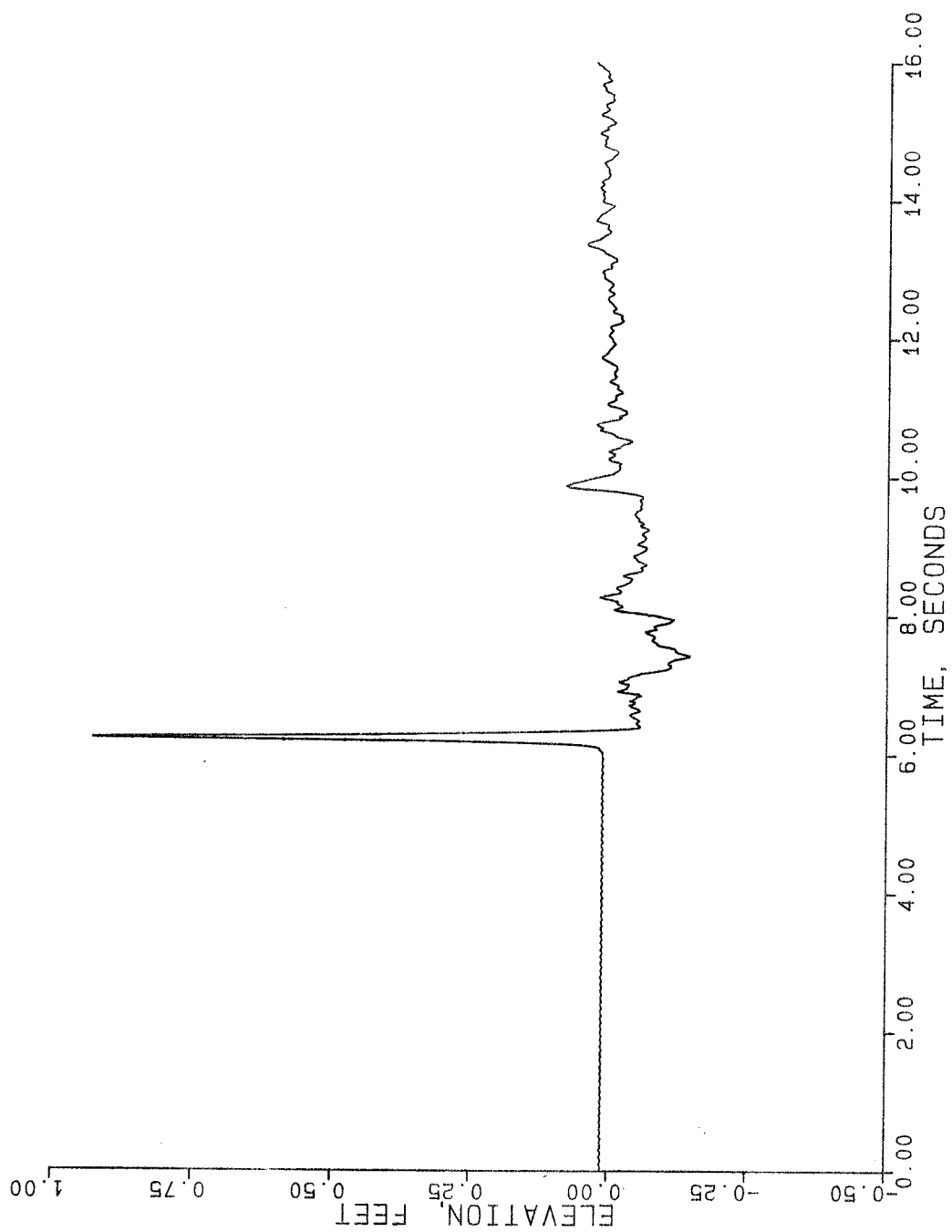




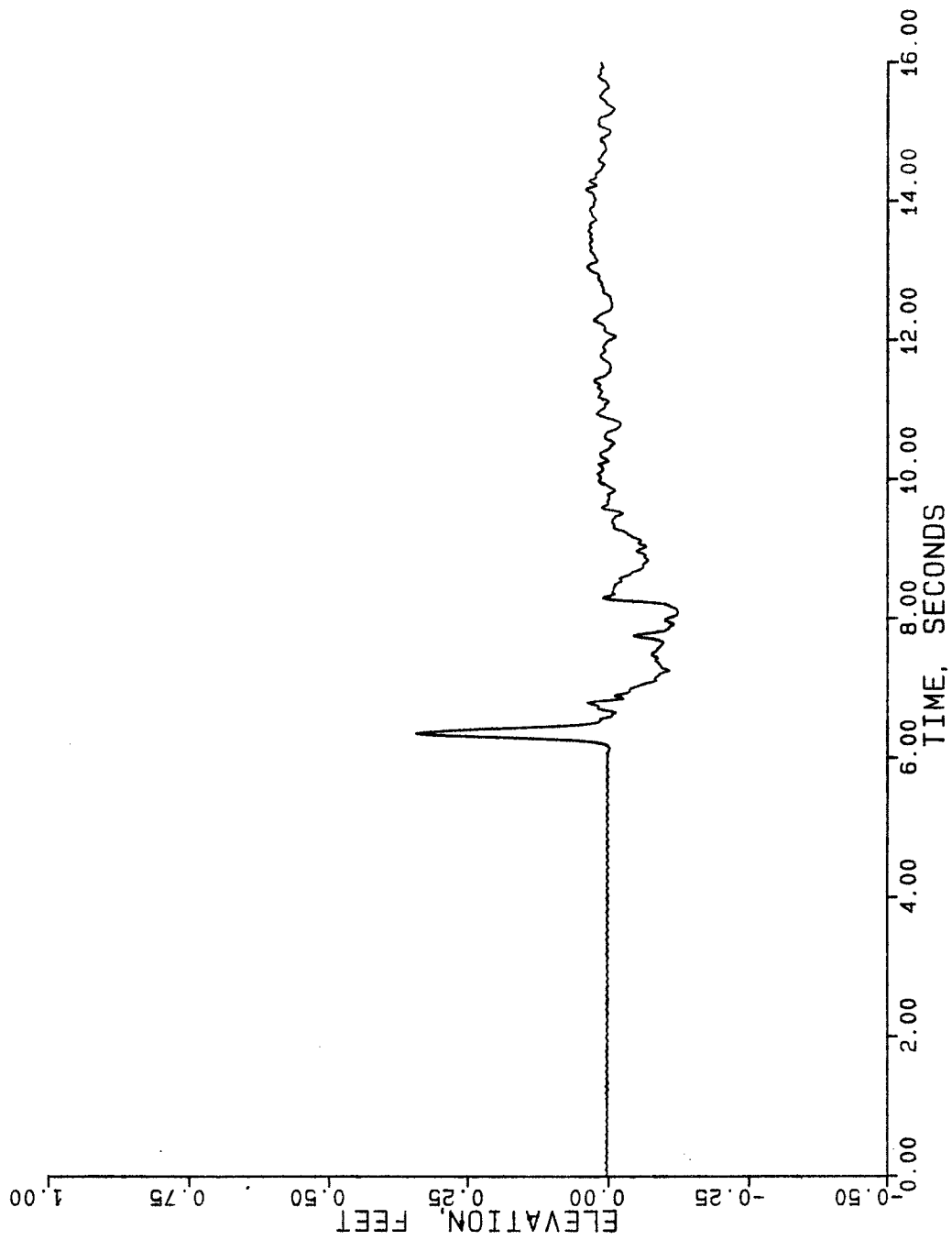
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 28. GAGE 2



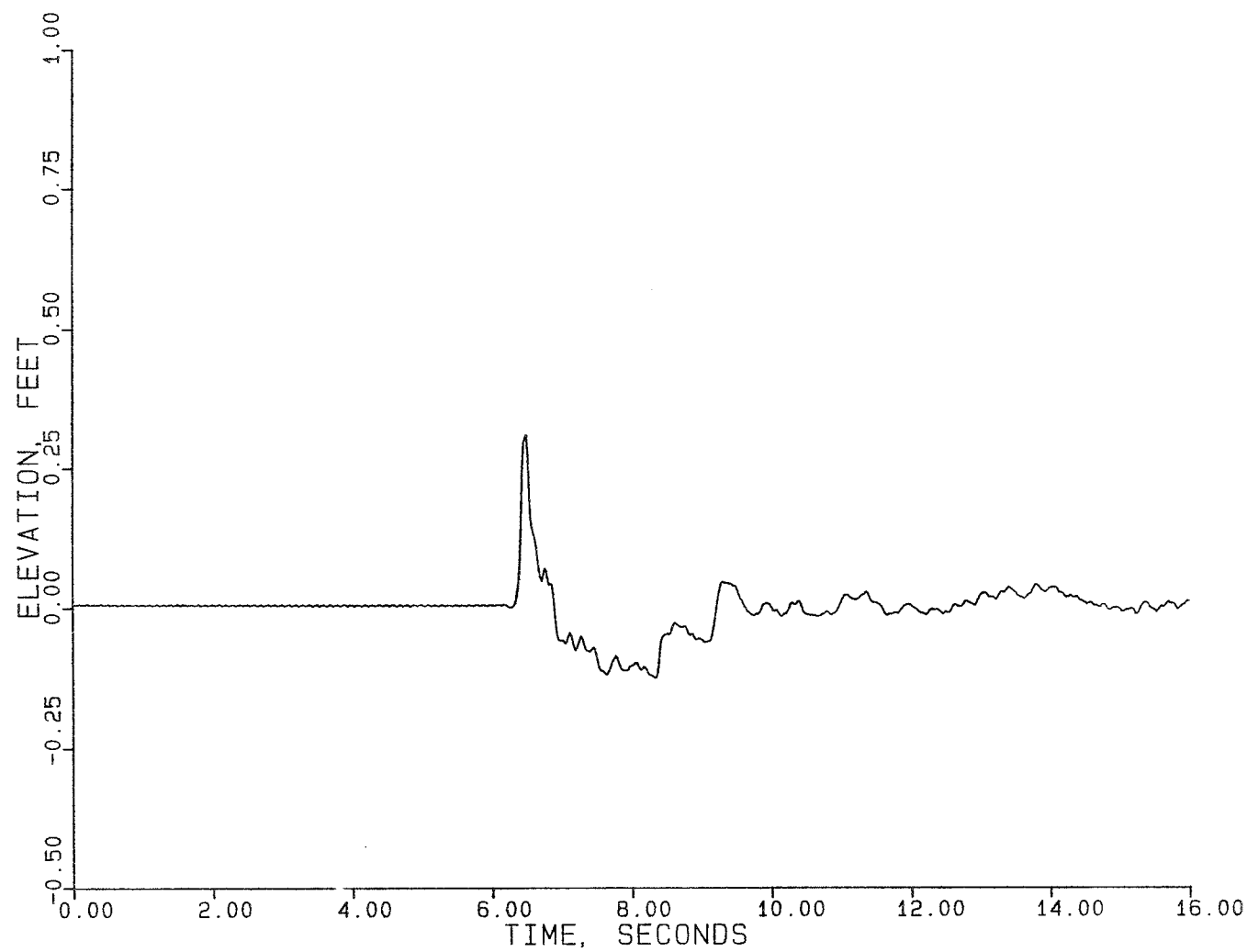
WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 28, GAGE 3



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 29, GAGE 1



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 29, GAGE 2



WAVE TRAIN TIME HISTORY  
IMPULSIVE GENERATED WAVES  
TEST 29, GAGE 3

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